Fisheries Research Bulletin No. 7

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An Analysis of the Statistics on the Fishery for Tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), in New Zealand Waters from 1936 to 1969, with Notes on the Trawl Fishery in General

By

C. M. Vooren

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New Zealand Ministry of Agriculture and Fisheries

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Frontispiece: Trawlers in the harbour of Gisborne, the centre of the East Cape tarakihi fishery, on 4 September 1972. *Michelle* is 45 ft in overall length, has a gross tonnage of 24 .9 and a 110 bhp diesel engine, and was built in 1948.

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FOREWORD

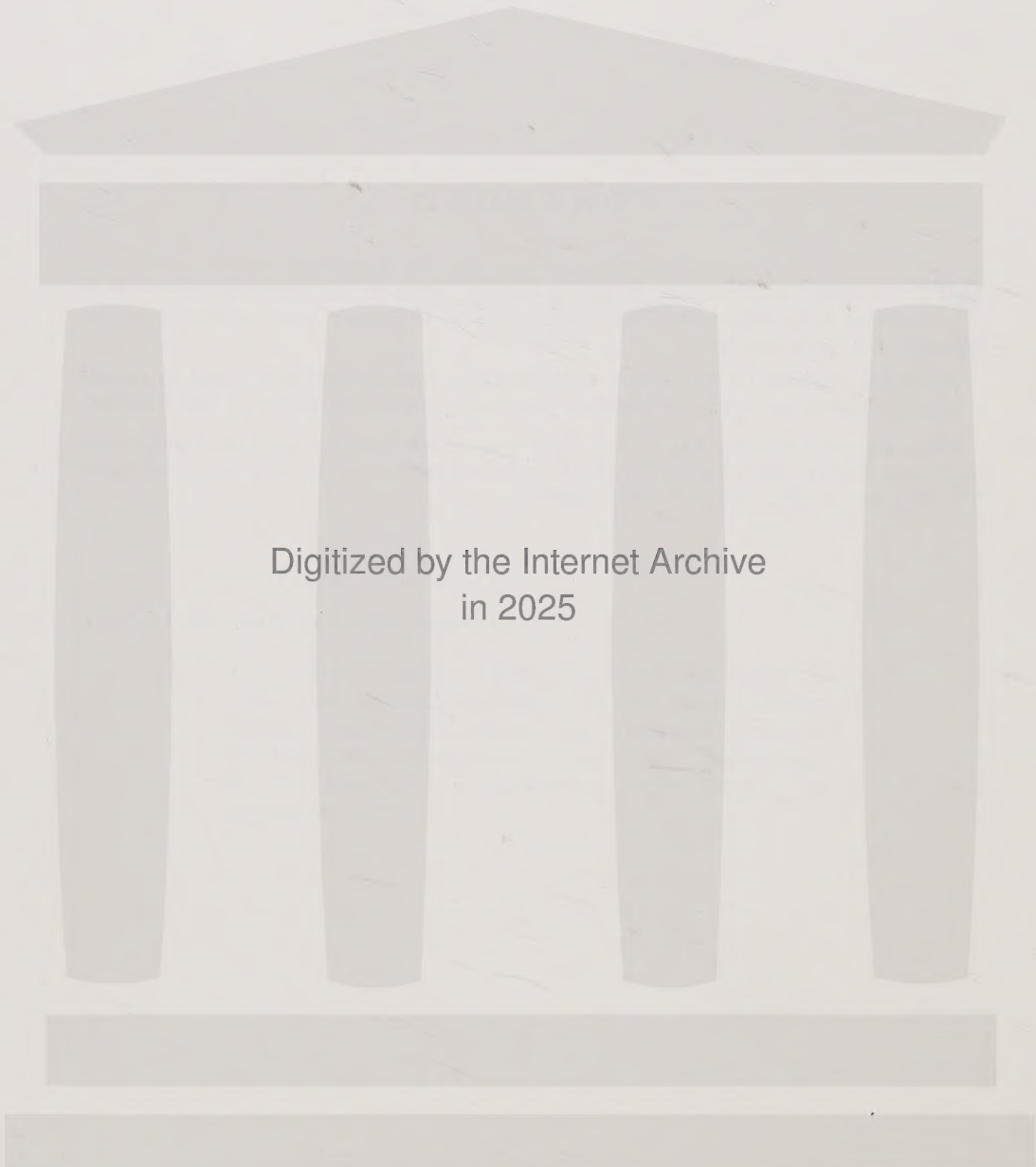
WITH a better appreciation of the biology of some of the more important New Zealand fish species, it is becoming possible to devote some attention to the fisheries for such species.

Available statistical data do not, unfortunately, contain sufficient detail to permit a wholly reliable comparison between past and present situations in the fisheries.

However, Mr Vooren has shown how these data may be used to further our understanding of the fisheries for the tarakihi as well as to provide some guidance for their use in the study of other fisheries.

G. DUNCAN WAUGH,

Director, Fisheries Research Division.



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INTRODUCTION

When a research programme on the population dynamics of the tarakihi was begun in 1968, the need was felt for a description of the trawl fishery in New Zealand and of the trawl fishery for tarakihi in particular. Slack (1969) reviewed the history of legislation and other governmental activities concerning the fishing industry and summarised recent economic data, but there has been no general account of the fishery itself describing methods used, fishing areas, fish species, and secular trends in catch and effort. This bulletin is intended to provide such an account on the basis of the statistical information collected systematically since 1936. For an interpretation of the recorded changes in the catches, a set of definitions relating to catch and effort was developed in such a way as to suit the available data (Appendix 1).

To evaluate the significance of secular changes in some characteristics of the trawl fishing fleet, the relationships between the fishing power and other parameters of trawlers were studied. There is no detailed information on the gear used in the New Zealand fishery at present, and modifications made on gear during the period under study (for example, Paul 1970, on Danish seining) have not been adequately described. The only fishing parameters measured under the present statistical system are vessel size, engine power, age of the vessel, and number of operators. As there is little variation in the last-named parameter, it has been ignored, but the others have been considered in relation to the fishing power of trawlers.

As the following analysis is completely in relative terms, "fishing power" indicates "relative fishing power", and "fishing effort" stands for "relative fishing effort". The statistical data on the fishery for the period under study are entirely in the British imperial units of length and weight, and these units are therefore used in this bulletin.

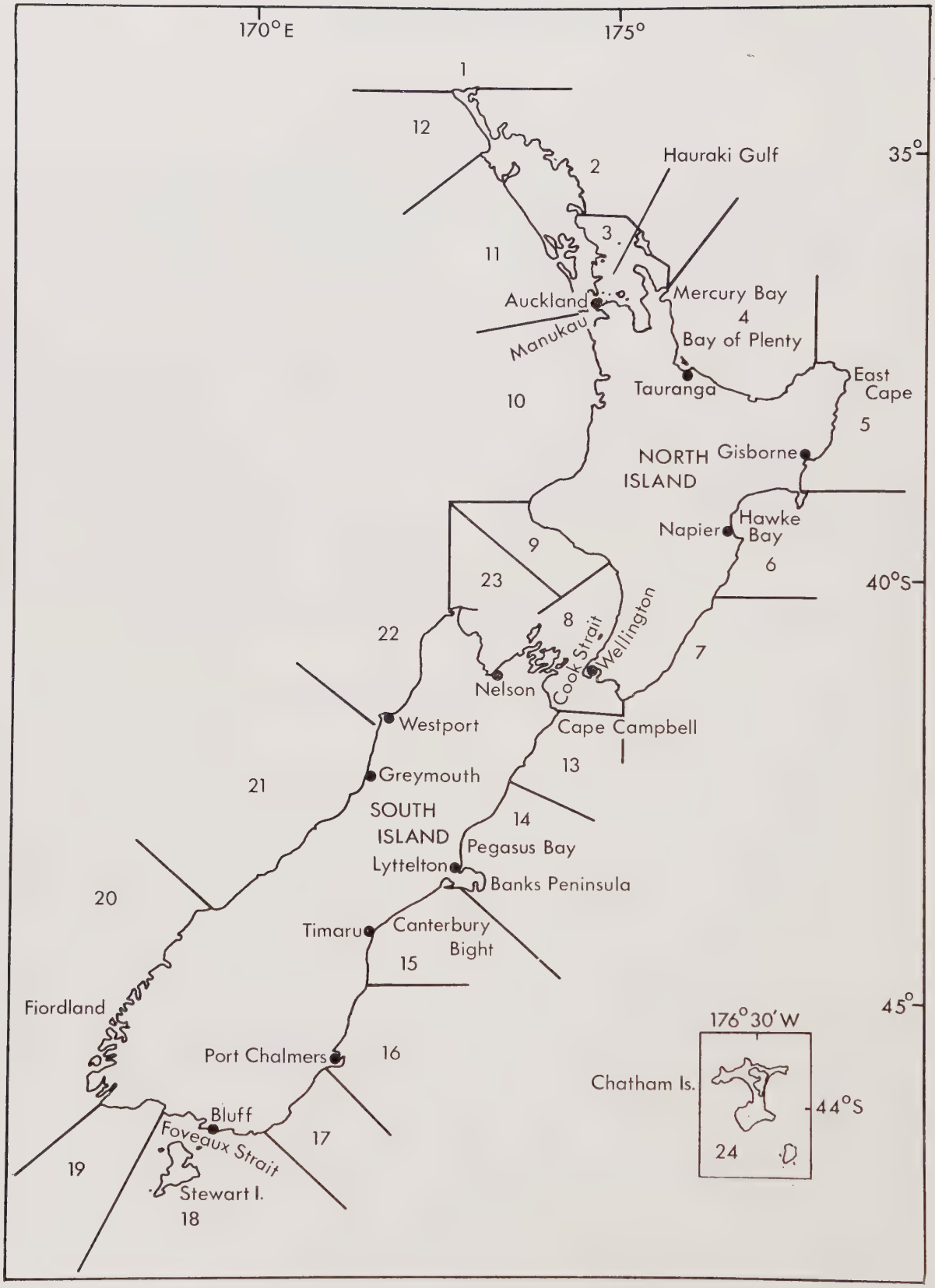

Fig. 1: Statistical areas and localities mentioned in the text.

THE STATISTICAL DATA

Statistical information on the New Zealand fishery is provided from three sources:

1. The data contained in the records of commercial fishing permits include information on the type and dimensions of the fishing units: type of gear used, numbers of operators, year of construction and overall length of fishing vessel, and type and brake horsepower (bhp) of engine. The measure of bhp is the maximum continuous rating as specified by the maker of the engine.

2. Larger fishing vessels are surveyed annually and the records provide data on their gross tonnage. However, this information is not available for the smaller craft, which are a significant part of the fishing fleet.

3. Since 1936 all commercial fishermen have been legally required to furnish returns stating for every fishing unit and for every month the number of landings and their dates, the port of landing, the "number of days fishing" for each landing, the "area fished", and the species composition of each landing by weight and value. For most species the landed weight refers to the whole fish. The "number of days fishing" refers to the number of days the vessel has been out of port and includes travelling time to and from the fishing grounds. "Days-at-sea" is therefore more appropriate, and this term is used in this bulletin. The information on "area fished" indicates in which of the 24 statistical areas the catches were made (Fig. 1).

Of the species of high commercial value, all legal-sized fish caught are usually landed, so that the landing figures also refer to the actual catches made. Of the less valuable species, variable quantities may be discarded at sea, so that the actual landings may bear little relation to the size of the catches. For individual trawl fishing trips between 2 and 49 percent of the total wet fish catch may be discarded. Barracouta, horse mackerel, trevally, and various elasmobranchs form the bulk of the discarded fish, but red gurnard, red cod, and kahawai are also affected (Jennings 1969, Reid 1969, Waugh 1969, Anon. 1970).

Since 1937 summaries of the data provided by the fishermen's returns and the licensing documents have been published in the Annual Reports of the New Zealand Marine Department*, hereafter referred to as the Annual Reports. They contain yearly data on landings by species, port, and fishing method and on size and composition of the fishing fleet. The data for the years 1936–69 were examined, and representative figures for this period, mostly selected at 5-year intervals, are quoted in this bulletin to illustrate general features of the fishery and long-term trends.

Statistics on catch and effort of individual boats were accessible only for the period 1961–69. These statistics are hereafter referred to as the "detailed statistics"; they include data on the number of days at sea, number of landings made, and quantities landed, all by month, and statistical area and species. Data from different years were selected to illustrate different features of the fishery during this period owing to variations between years in the amount and accessibility of certain data. For a regional comparison the data for three statistical areas were examined in detail: Area 5 (East Cape) was selected as the principal tarakihi fishing area and a typical North Island trawling area, and areas 14 (Pegasus Bay) and 15 (Canterbury Bight) were selected as typical South Island trawling areas.

* The Marine Department ceased to exist as a separate department of State on 1 September 1972. The statistical information included in the Annual Reports of the Marine Department was prepared by the Fisheries Management Division, which with the Fisheries Research Division was transferred to the Ministry of Agriculture and Fisheries on 1 September 1972.

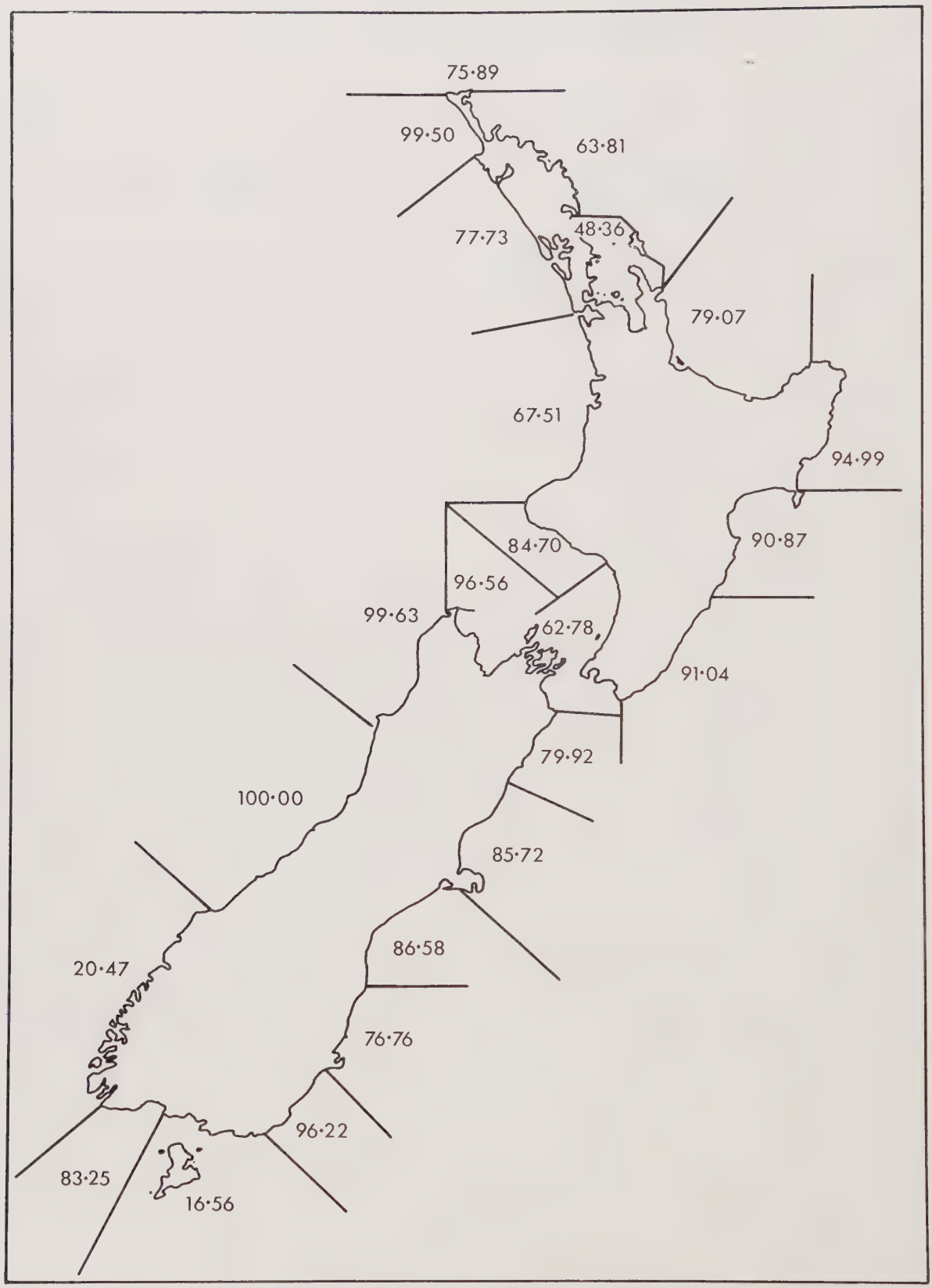

Fig. 2: The percentage of the total wet fish landings accounted for by motor trawlers in each statistical area in 1967.

THE TRAWL FISHERY IN GENERAL

IMPORTANCE OF MOTOR TRAWLING

During the period under study trawling has steadily increased in importance, and nowadays the bulk of the wet fish landings is provided by this method. In 1965 and 1969, for instance, trawling accounted for 80 percent of the total wet fish landings. Until 1950 steam trawlers were an important section of the trawler fleet, but they have been gradually replaced by diesel-powered motor trawlers; the last steam trawler ceased to operate in 1965 (Table 1). On a national scale Danish seining is of minor importance, but in the Hauraki Gulf it is traditionally one of the principal methods used. The Danish seine fishery in the latter area is described in detail by Paul (in press).

There are regional differences in the importance of trawling (Fig. 2). In most areas trawling has accounted for more than 70 percent of the total wet fish landings, but important exceptions are the east Auckland coast, Cook Strait, eastern Foveaux Strait, and Fiordland. Intensive line fishing and shore netting in these areas and much Danish seining in the Hauraki Gulf are the reasons for these exceptions.

THE TRAWL CATCH

The species composition of the New Zealand trawl catch as a whole is extremely varied. The Annual Reports for 1969 list 32 "species", some of which denote groups of several biological species, which may be taxonomically quite unrelated. There are, however, only seven dominant species or species groups. For many years snapper, tarakihi, and red gurnard have dominated strongly, comprising up to 70 percent of the total trawl landings. In recent years trevally has been landed in increasing quantities and since 1969 has replaced red gurnard as the third most important wet fish species (Table 2).

The change in the species composition of the motor trawler landings between 1945 and 1950 reflects the rapid expansion of motor trawling in the North Island during those years; previously motor trawling occurred mainly in the South Island, where snapper and trevally are scarce and where elephant fish and the various species of sole dominated the landings.

In the individual fishing areas the total wet fish catches also include a great variety of species. However, there are some areas in which one or two species dominate strongly. The Annual Reports show that the annual landings from the Auckland region (areas 2 and 3) always consist of more than 50 percent of snapper. Port Chalmers (areas 16 and 17) is typically a port for "sole", and Bluff (area 18) is one for blue cod. The Timaru landings (area 15) are characterised by large quantities of red cod and elephant fish. The tarakihi is of great importance along the east coast of the North Island from Mercury Bay southward (areas 4 to 7), in Cook Strait (area 8), and in the region between Cape Campbell and Banks Peninsula (areas 13 and 14).

THE TRAWL FISHING EFFORT

A rough measure of the motor trawl fishing effort is provided by the number of registered motor trawlers listed in the Annual Reports. This number has steadily increased from 52 in 1936 to 324 in 1969, excluding the boats at the Chatham Islands (Table 1). The trawlers registered at the latter locality have not been included in the following analysis because they are principally rock lobster fishing boats that land little or no fish, but hold a trawling permit mainly to catch bait for their own use. Similar phenomena also occur to some extent elsewhere in New Zealand. The number of registered motor trawlers therefore overestimates the actual trawl fishing effort. This bias in the data is assumed to be constant, so that it is possible to compare

TABLE 1: Total wet fish landings and percentages taken by the various fishing methods (landings by Chatham Islands motor trawlers excluded)

Year	Total wet fish (cwt)	Steam trawlers		Motor trawlers		Danish seiners		Other fishing units
		% of catch	No. of boats	% of catch	No. of boats	% of catch	No. of boats	% of catch
1936	363,128	28	24	7	52	32	74	33
1940	328,594	12	10	14	91	40	58	34
1945	331,773	14	10	21	96	32	49	33
1950	440,179	18	7	44	176	10	25	28
1955	435,335	6	3	64	229	5	13	25
1960	542,506	4	3	68	244	6	14	22
1965	604,582	Unknown	1	79	292	4	13	16
1969	645,012	0	0	71	324	11	34	16

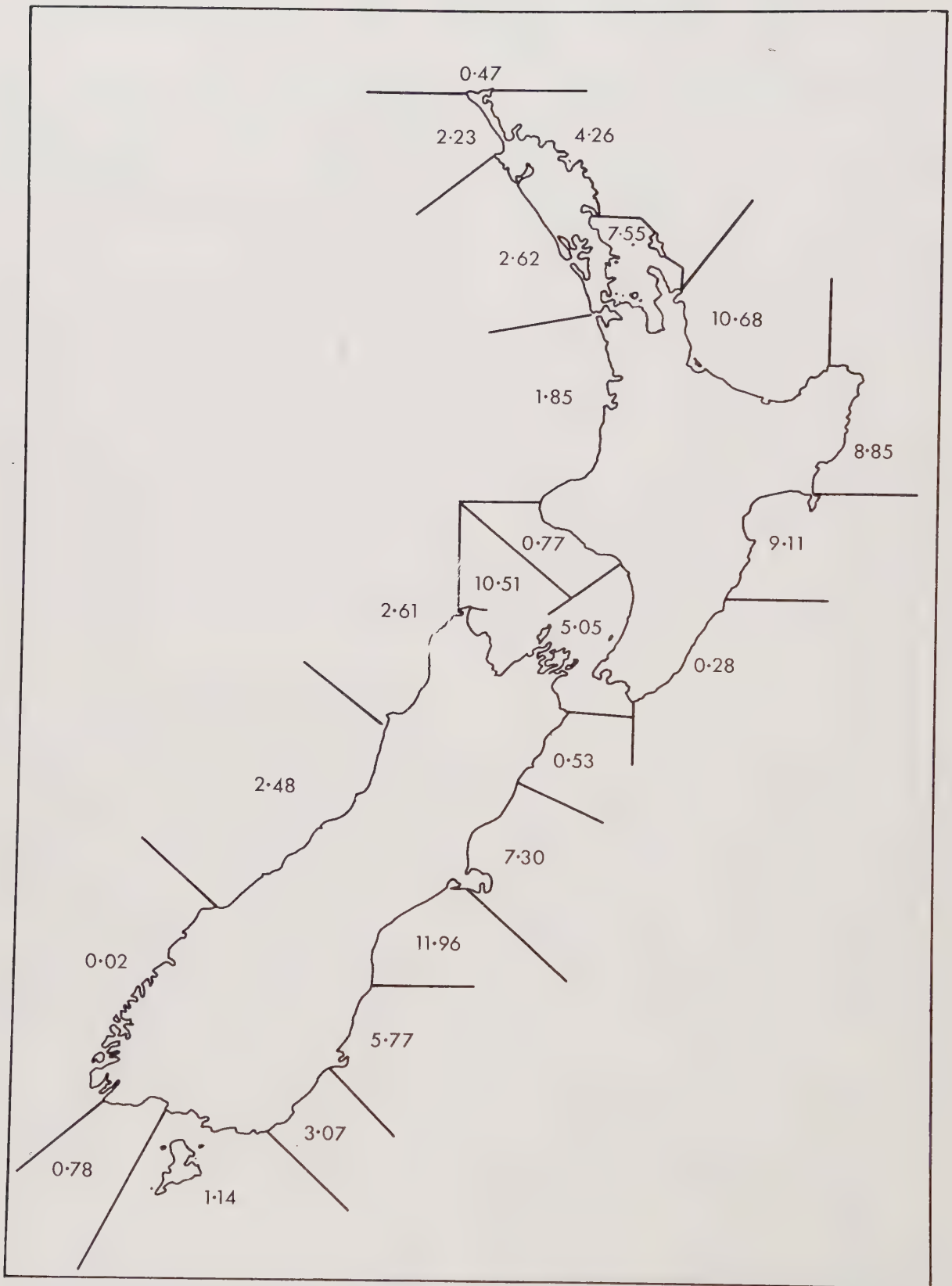

Fig. 3: The percentage of the total New Zealand motor trawl fishing effort in each statistical area in 1967. The unit of effort is the motor trawler-day-at-sea.

TABLE 2: Percentual species composition of total motor trawler catch

Species	1936	1940	1945	1950	1955	1960	1965	1969
Snapper	1	2	3	22	26	26	26	29
Tarakihi	2	18	27	33	32	28	25	15
Red gurnard	6	12	14	11	12	12	14	11
Trevally	0	1	1	2	5	9	9	13
Sole	34	27	24	12	6	6	4	4
Elephant fish	3	7	5	6	6	6	4	4
Flounder	4	5	7	3	3	2	2	2
Others	51	29	20	12	11	11	15	22

effort and catch/effort data for the mainland of New Zealand from year to year in terms of trawler-years.

Motor trawling developed first in the South Island, where in 1940 Timaru and Port Chalmers were the most important ports, the only major port in the North Island being Napier. Between 1945 and 1950 motor trawling expanded rapidly in both the North Island and the South Island, especially at Auckland, Nelson, and Lyttelton, and Gisborne and Tauranga have shown rapid growth since 1960. Trawling at present is most intensive in statistical areas 3 to 6, 14, 15, and 23. In 1967 these seven areas together sustained 66 percent of the total fishing effort in terms of trawler-days-at-sea (Table 3, Fig. 3).

TABLE 3: Numbers of motor trawlers registered at the main fishing ports, with numbers of unit motor trawlers in parentheses (1 steam trawler=6 unit motor trawlers)

Port	1936	1940	1945	1950	1955	1960	1965	1969
Auckland	0 (18)	0	0 (12)	18 (36)	27	29	32	34
Tauranga	0	0	1	3	4	6	8	10
Gisborne	3 (9)	5	2	9	8	9	20	23
Napier	5 (47)	12 (18)	13 (19)	16	15	14 (20)	16	19
Wellington	0 (16)	2 (14)	1 (13)	2 (20)	4 (22)	8 (20)	9 (15)	7
Nelson	0	2	2	11	11	11	16	14
Lyttelton	7 (23)	3 (15)	9 (15)	11	14	13	21	16
Timaru	10	16	13	23	25	27	30	22
Port Chalmers	17 (29)	14 (20)	16	22	24	22	20	25

While the number of trawlers increased, the vessels also underwent considerable changes. Between 1946 and 1966 the mean overall length of motor trawlers increased from 38.8 to 48.0 ft, an increase of 24 percent. By substituting these lengths in equation 15 (Appendix 2) it was found that the gross tonnage of the average motor trawler increased by 60 percent from 16.5 to 26.4. The mean bhp increased by 240 percent from 40.0 in 1946 to 135.9 in 1966. The maximum length increased from 58 to 108 ft, and the maximum bhp from 165 to 450. There are some pronounced regional variations in the average size and bhp; the trawlers of the two largest North Island fishing ports, Auckland and Gisborne, are at present considerably larger and have more powerful engines than those operating on the east coast of the South Island. Auckland and Lyttelton are the two extremes in these respects (Table 4).

The size of the crew of motor trawlers varies at present between 1 and 3. The estimated national average was 2.4 in 1970, ranging between 3.0 for Auckland and 2.0 for Lyttelton.

Compared with the motor trawlers, the steam trawlers were large fishing units, ranging from 69 to 128 ft in overall length, and most of them were

TABLE 4: Mean and range of length and engine bhp of motor trawlers

Port	Year	Length (ft)	bhp	Sample size	Size of fleet
Auckland	1968	53.3 (37-70)	187.1 (44-430)	34	34
Gisborne	1956	48.2 (41-60)	102.0 (40-120)	7	8
	1961	50.6 (41-60)	155.5 (110-230)	11	11
	1968	56.3 (34-76)	181.8 (57-340)	22	24
Napier	1946	44.5 (35-49)	77.0 (32-165)	4	15
	1956	45.5 (35-55)	93.0 (30-165)	11	16
	1966	50.7 (26-75)	160.1 (30-330)	17	24
Wellington	1956	42.2 (24-55)	110.2 (12-220)	6	6
	1966	52.4 (40-68)	178.6 (110-245)	7	9
Lyttelton*	1968	42.0 (18-69)	107.5 (20-340)	19	19
Timaru	1968	44.1 (20-69)	118.7 (12-340)	23	23
All ports	1946	38.8 (26-58)	40.0 (7-165)	38	110
	1956	43.7 (21-60)	87.6 (10-162)	119	229
	1966	48.0 (20-108)	135.9 (12-450)	170	325

* An atypically large motor trawler, of 126 ft and 650 bhp, is not included in the figures for Lyttelton.

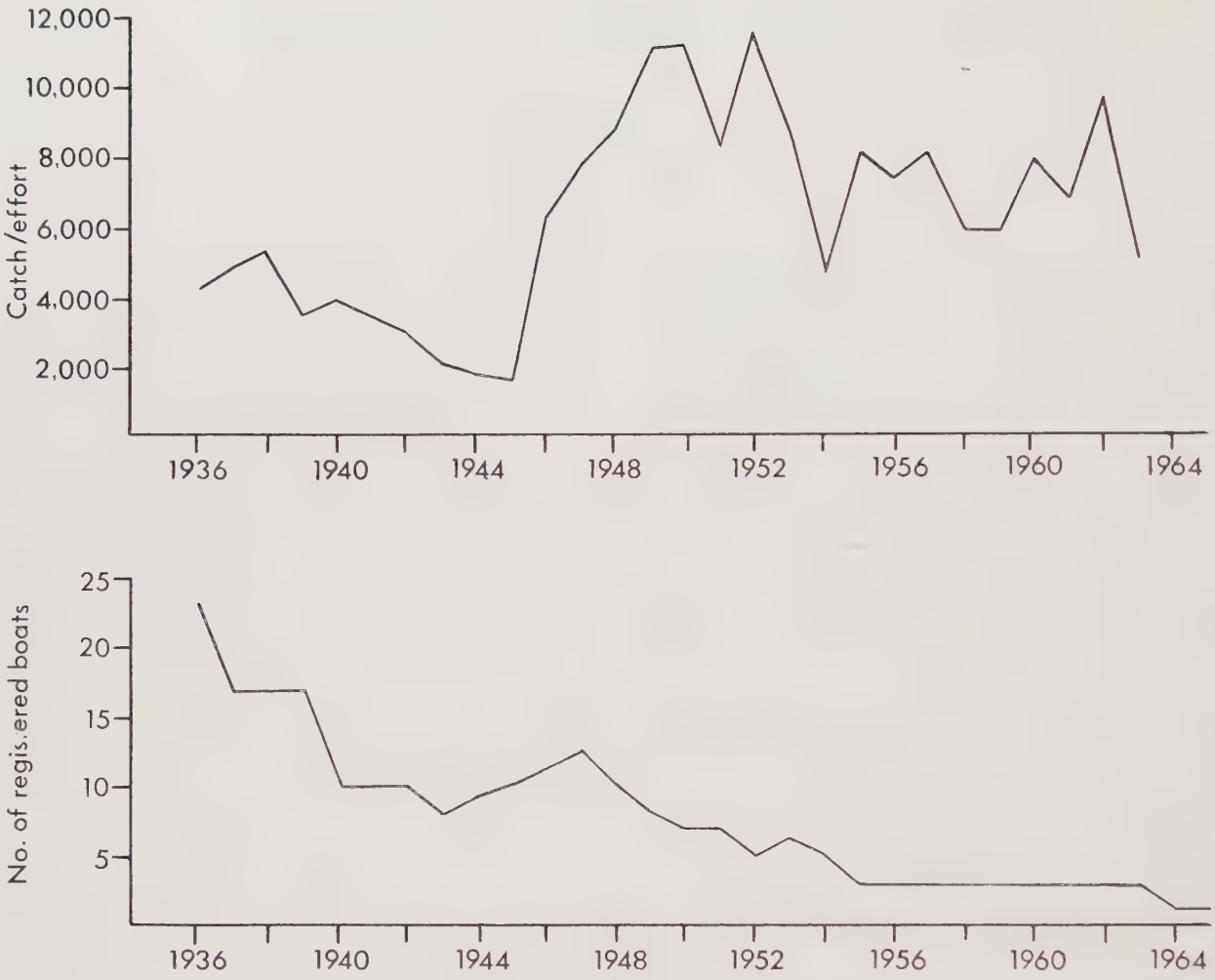

Fig. 4: The effort (as indicated by the number of registered boats) and catch/effort (in hundredweight/trawler-year) of all steam trawlers for total wet fish.

larger than 100 ft. The size of crew varied from 2 to 11 and was mostly 8 or more. These figures are based on data for only 11 steam trawlers; data on this extinct type of fishing unit are not readily accessible.

Before 1963 fishermen were permitted to land their catches only at their port of registration. This "restrictive measure" has been stated as "hindering the logistic efficiency of fishing operations", by forcing trawlers to limit their activity to the vicinity of their home ports (Slack 1969, page 14). Though this legal restriction was lifted in 1963, the pattern has remained almost unchanged, so that even at present the working ranges of the various local trawler fleets do not overlap much. Thus, catch and effort data by ports refer mainly to the fishery in the vicinity of the ports and vice versa. The trawlers from most ports therefore tend to make short fishing trips of 1 to 2 days. The trawlers from Auckland (including Manukau) are exceptional in that they make trips of 4 to 7 days. This is a result of the legal restrictions on trawling in the Hauraki Gulf, which force these boats to work in more distant areas (Paul in press).

The New Zealand trawlers are active throughout the year, and there are no marked seasonal fluctuations in their activity. The average time spent annually at sea by a full-time motor trawler is about 100 to 160 days, varying from port to port (Table 5).

CATCH/EFFORT ANALYSIS OF THE ANNUAL REPORTS

In the analysis of the data contained in the Annual Reports of the New Zealand Marine Department, the steam trawler-year or motor trawler-year was used as the unit of fishing effort, and the annual wet fish landings were taken as an index of the catch.

The catch/trawler-year of the steam trawlers (Fig. 4) declined considerably during 1940–45 as

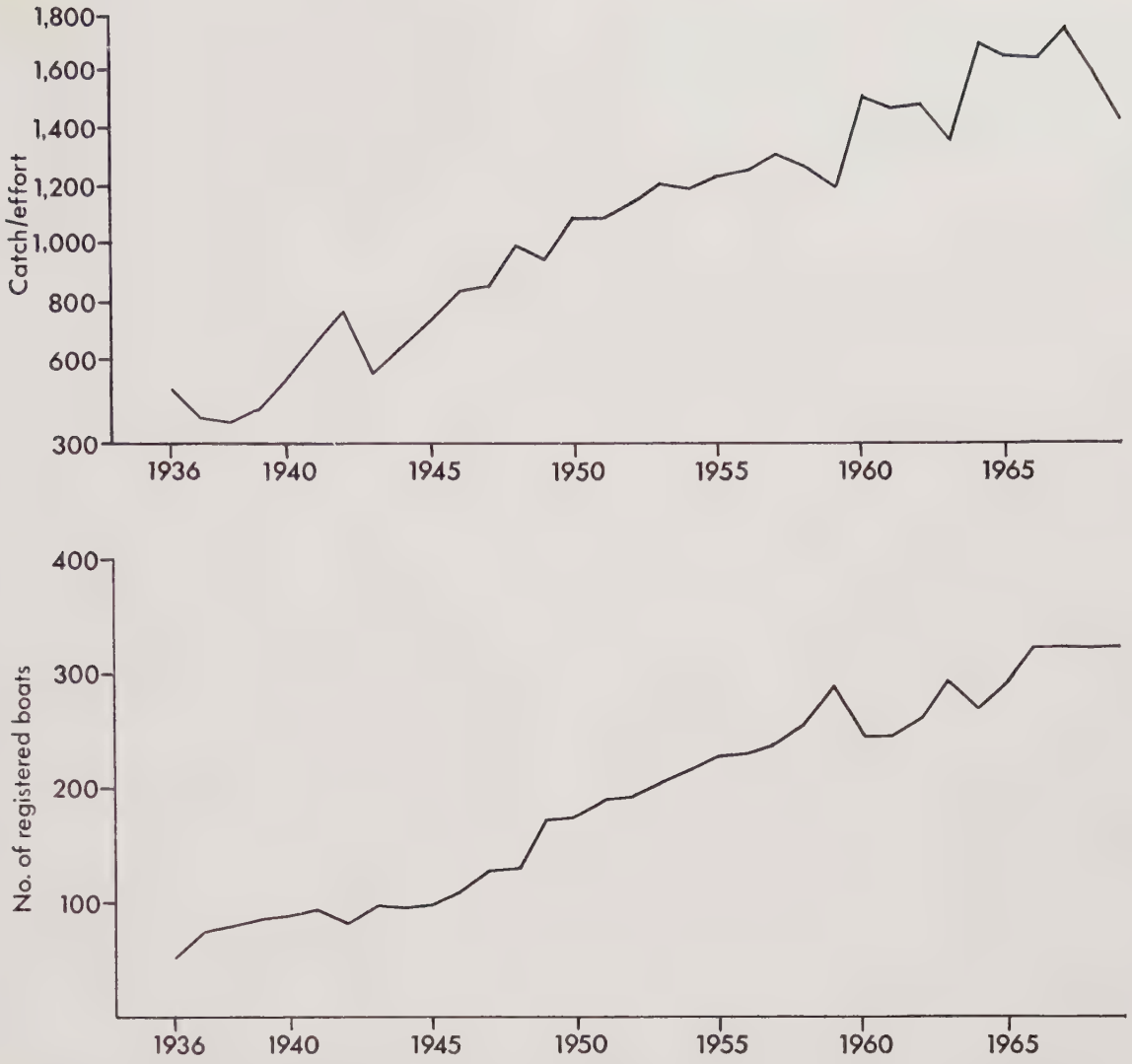

Fig. 5: The effort (as indicated by the number of registered boats) and catch/effort (in hundredweight/trawler-year) of all motor trawlers for total wet fish.

a result of conditions arising from the war (New Zealand Marine Department 1946). The catch/trawler-year increased in 1946 and fluctuated subsequently around 8,000 cwt/year. The number of steam trawlers decreased from 11 in 1946 to 1 in 1964, and this vessel stopped fishing in the following year. Since the catch/trawler-year remained fairly stable, the decline of the steam trawler fleet was probably a result of economic factors affecting the profitability of the vessels.

The catch/trawler-year of the motor trawlers increased from 487 cwt/year in 1936 to 1,417 cwt/year in 1969 (Fig. 5). The species composition of the motor trawler landings has remained very

TABLE 5: Mean number of days spent at sea per trawler in 1967 and 1968 for four major ports

	All trawlers				Full-time trawlers†			
	Days at sea		No. of boats		Days at sea		No. of boats	
	1967	1968	1967	1968	1967	1968	1967	1968
Gisborne*	106 (1-213)	97 (5-183)	26	25	144 (83-213)	128 (59-183)	14	16
Wellington	61 (6-146)	58 (3-157)	11	8	101 (46-146)	121 (64-157)	4	3
Lyttelton	75 (6-165)	59 (2-159)	21	22	113 (81-165)	100 (59-159)	11	9
Timaru	119 (9-218)	129 (5-217)	30	24	165 (121-218)	153 (83-217)	17	18

* The figures for Gisborne include data on one Wellington trawler landing mainly at Gisborne.
† Full-time trawlers are those landing catches during at least 9 months of the year.

similar since 1950 (Table 2), which indicated that the landings of all major species have increased at the same rate. Exceptions are tarakihi, landings of which have decreased considerably since 1968, and trevally, landings of which have increased faster since 1955 than those of the other species. The trevally is not a very valuable commercial species, though it has increased in market value since 1955 (Table 6), and the increase in landings is probably partly due to the fact that less trevally is now discarded at sea. The same may apply to the increase in the red gurnard landings. The other dominant species are all valuable fishes, so that the increase in the landings of these species undoubtedly reflects an increase in the catch.

CATCH/EFFORT ANALYSIS OF THE DETAILED STATISTICS

The performance of a trawler is its average catch per day-at-sea. The monthly and annual performances of motor trawlers operating between 1961 and 1968 in statistical areas 5, 14, and 15 were calculated. The relationships between these performances and four vessel characteristics (length, bhp, age, and gross tonnage) and between these vessel characteristics themselves were examined by means of linear regression techniques. The calculations and results are described on pages 39–40. As only the statistics for motor trawling were analysed, "trawler" stands in this section for "motor trawler".

The results indicated that the detailed statistics were suitable only for an analysis on an annual basis, without weighting the data on individual boats by the number of days spent at sea. The age of a trawler was found to have little influence on its overall performance, and the same applied to bhp in so far as it varied independently from length. As a variable bhp was strongly correlated with length and was therefore largely included when length alone was considered. The data for areas 14 and 15 showed that the independent variation of bhp may be of some importance in certain areas, though even there, the correlation between annual performance and length alone was already very high. Overall boat length can be measured easily and accurately, whereas the measurement of bhp is much more difficult and is not regularly made on New Zealand trawlers. The data on length are therefore much more reliable than those on bhp. Though gross tonnage is widely considered to be the best vessel parameter to use in studies of fishing power (for example, Gulland 1956, Zijlstra and de Veen 1963), the present data indicate that in the New Zealand trawl fishery length is equally suitable or even better. A major reason for this is that at present the gross tonnage is known only of vessels exceeding 40 ft, and the above conclusion may need to be revised when data on gross tonnage become available for the whole fleet.

The correlation between boat length and total annual performance found for areas 5, 14, and 15 can be interpreted in terms of fishing power if the concepts defined in Appendix 1 are applied to the total of the stocks of all wet fish species in these areas each year. The abundance then becomes the total amount of marketable fish of all species in a given sea area, and the absolute fishing power is the average proportion thereof taken per day-at-sea by a trawler. Within each area and year, all boats operated under the same conditions of abundance, as defined in this way. Variations in performance therefore reflect variations in absolute fishing power, and the data indicate that the standard fishing unit can be defined in terms of boat length. The length of the average New Zealand trawler is at present about 50 ft. The unit of effort was therefore defined as 1 day-at-sea by a 50-ft trawler. Analyses of the overall wet fish catch/effort and of the relationship between relative fishing power and boat length are described in Appendix 2.

The overall catch/effort provides an index of the abundance of marketable fish in areas 5, 14, and 15. The results show that in area 5 the abundance of marketable fish has been fairly stable from year to year between 1962 and 1968 (see Table 15). The catch/effort estimates for areas 14 and 15 in 1966–68 were similar and were all much lower than the general level of catch/effort observed in area 5. These results suggest major differences in the abundance of marketable fish between fishing areas. Regional differences in the size, type, and efficiency of the trawl gear used also undoubtedly exist, so that the absolute fishing power of trawlers of similar size may vary from area to area. The present data allow no conclusions on these points, but indicate certain aspects of the fishery that need to be studied further.

TABLE 6: Commercial value of fish species (the figures for southern kingfish include small amounts of yellowtail and southern hake)

Category	Value/cwt landed (NZ$) 1955	1969
"Bait" (for use in rock lobster fishery)	not listed	2.21
Barracouta	2.36	2.29
Horse mackerel	2.43	2.41
Warehou	5.24	5.52
Trevally	2.59	3.11
Snapper	5.11	6.66
Tarakihi	4.89	7.16
Red gurnard	3.73	4.58
Elephant fish	7.47	18.00
Flounder	14.84	20.88
Sole	12.82	17.21
Southern kingfish	7.89	7.83

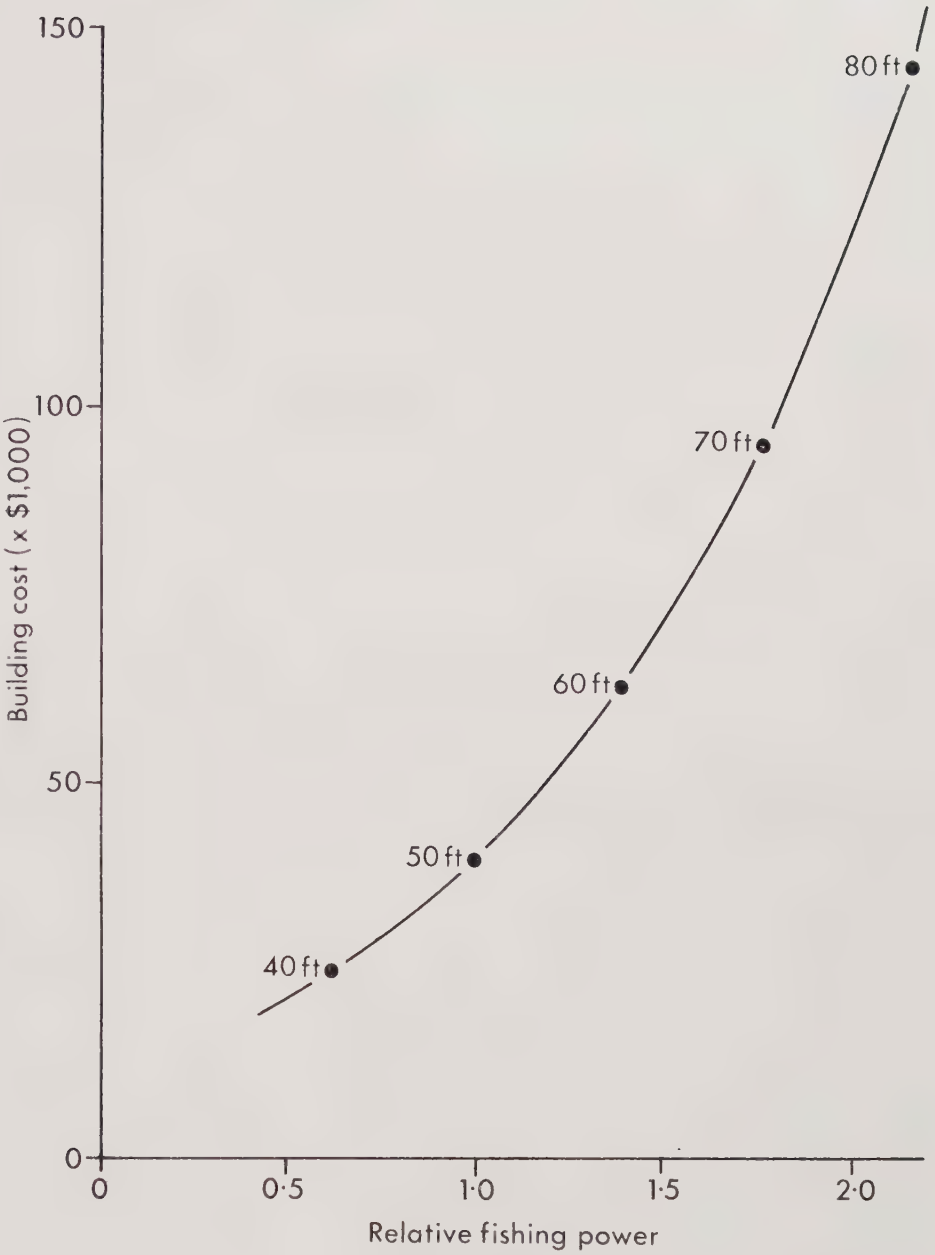

Fig. 6: The relationship between overall length, relative fishing power (for total wet fish), and total building cost for motor trawlers in area 5. Building cost is as at 1 March 1968, quoted by Breekveldt (1969, Fig. 2) for steel fishing boats.

The data yielded a linear regression equation expressing the relationship between relative fishing power and boat length in area 5 and indicated that the same relationship might hold for other areas as well (equation (15), Appendix 2). If this equation is applied to the data on the average length of New Zealand trawlers given in Table 4, it appears that between 1946 and 1966 the average relative fishing power of the trawlers has almost doubled: 0.578 in 1946 and 0.925 in 1966. The 50-ft trawler-year was applied as relative unit of effort to the statistical data for these years on the fishery as a whole, as given in the Annual Reports. This treatment gave similar catch/effort figures for both years: 1,437 cwt/50-ft trawler-year for 1946 and 1,774 in 1966 (Table 7). Though these catch/effort estimates for the New Zealand motor trawl fishery as a whole can be regarded only as a rough approximation, they do indicate that the catch/effort in both years was about the same magnitude. Thus the large increase of the wet fish catch per trawler-year from 830 cwt in 1946 to 1,640 cwt in 1966 can largely be accounted for by the increasing boat size.

Information on relative fishing power and effort for all commercial demersal species together has little biological meaning, but can be useful in combination with certain economic data on fishing boats. As an example of this Fig. 6 shows the positive

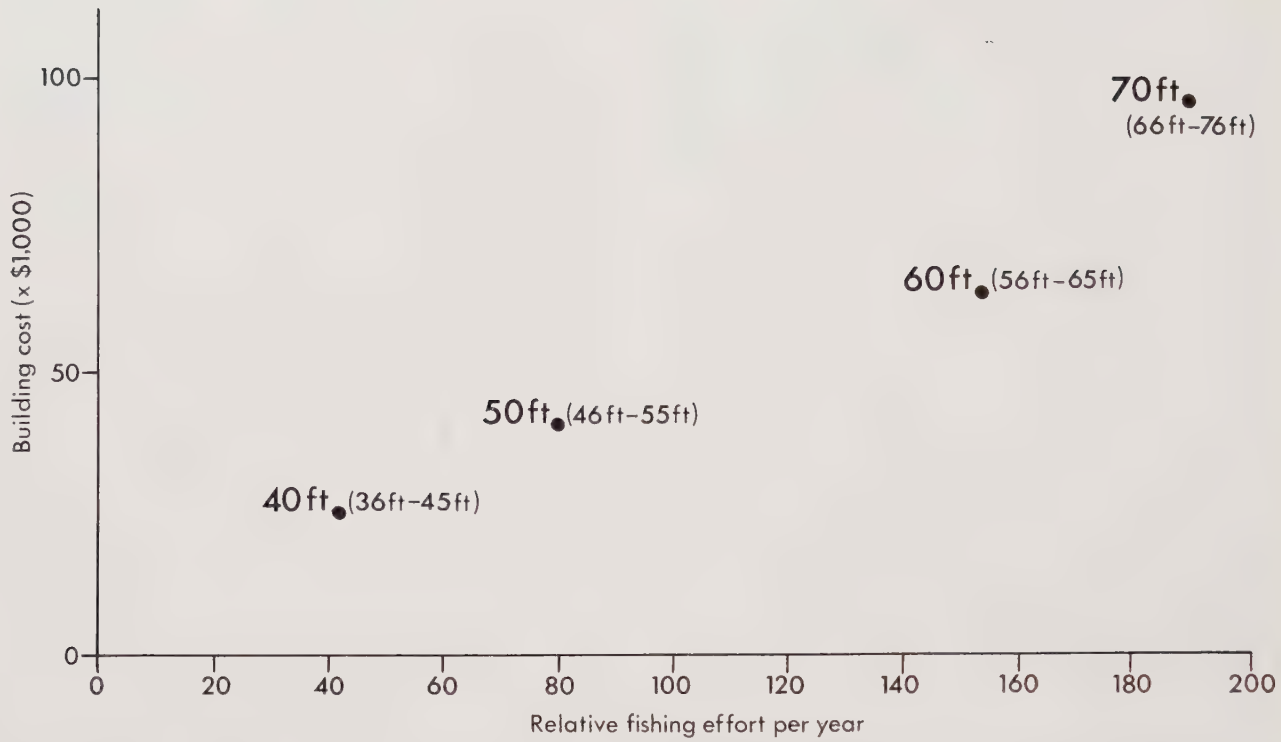

Fig. 7: The relationship between overall length, relative fishing effort (for total wet fish) per year, and total building cost for motor trawlers in area 5. The unit of effort is the day-at-sea by a 50-ft boat. Fishing effort is estimated by the mean number of days fished per boat per year by 10-ft length groups, over 1966-68, multiplied by the relative fishing power of the midpoint of the length group. The figure for the 70-ft trawler includes values for a 76-ft vessel. The building cost is estimated as in Fig. 6.

relationship between the building cost of trawlers of certain sizes, as quoted by Breekveldt (1969), and their relative fishing power, as calculated for area 5. The relationship is clearly curvilinear. With increasing boat length the relative fishing power increases faster than the building cost up to a length of about 55 ft, but above this point the reverse occurs. However, the larger boat is nevertheless an economic proposition in terms of building cost in area 5, because the relationship between building cost and relative fishing effort per year is nearly linear (Fig. 7). This is due to a positive relationship between boat size and time spent annually at sea.

TABLE 7: Relative wet fish catch/effort (in hundredweight/50-ft trawler-year) for New Zealand trawlers in general for 1946 and 1966

Year	1946	1966
Number of motor trawlers	110	325
Average relative fishing power of motor trawlers	0.578	0.925
Relative fishing effort (50-ft trawler-years)	63.547	300.463
Total catch by motor trawlers (cwt)	91,347	533,152
Motor trawler catch/effort (cwt/50-ft trawler-year)	1,437	1,774

THE TARAKIHI FISHERY

Tarakihi is almost exclusively landed by trawlers, so that many features described for the trawl fishery in general apply also to the tarakihi fishery (Table 8). Since 1960 the East Cape region (area 5; port Gisborne) has been by far the most important tarakihi fishing area. The other major areas are the Bay of Plenty (area 4; port Tauranga), Cook Strait (areas 8 and 13; port Wellington), Hawke Bay (area 6; port Napier), and Pegasus Bay (area 14; port Lyttelton). In 1967, 40 percent of the combined landings from these areas consisted of tarakihi, and these landings accounted for 66 percent of the total landings of that species. In 1967 and 1968 the west coast of the South Island (areas 21 and 22) also produced much tarakihi owing to the activities of two large deep-sea trawlers operating from Nelson during these years only. In previous years little fishing took place in this region, and the proportion of tarakihi in the landings was small, as the figures for 1966 indicate (Table 9, Figs. 8 and 9).

TABLE 8: Total tarakihi landings and percentages taken by the various fishing methods (for 1965 one steam trawler has been included with the motor trawlers)

Year	Catch (cwt)	Steam trawlers (%)	Motor trawlers (%)	Danish seiners (%)	Others (%)
1936	53,114	89	1	8	2
1940	45,334	49	18	31	2
1945	63,829	42	30	25	3
1950	108,771	37	59	4	0*
1955	111,771	19	79	1	1
1960	117,617	12	87	1	0*
1965	118,367	0	100	0*	0*
1969	71,007	0	100	0*	0*

* Small percentage rounded off to zero.

Most of the large tarakihi landings made at Auckland between 1945 and 1955 were caught at great distances from the home port (Jennings 1969). The detailed statistics show that the Auckland fleet gradually withdrew from area 5 in 1960–65 and since then has operated mainly in areas 2 and 3, ranging into areas 1 and 4 only to a small extent. It is not known how much tarakihi was caught in the East Cape area by the Auckland trawler fleet and landed at Auckland before 1960, so that the total quantity taken in this area up to 1960 is difficult to estimate. However, even in the earlier years the trawlers registered at Gisborne operated mainly near their home port. The catch/effort data for the Gisborne trawler fleet therefore provide an index of the abundance of the tarakihi in the East Cape area before 1960, even if the total catch and effort in the area are not known.

CATCH/EFFORT ANALYSIS OF THE ANNUAL REPORTS

The unit of effort used in this section is the motor trawler-year. The tarakihi catch/effort was determined for Gisborne, Napier, and Wellington, where between 1940 and 1969 tarakihi has on average constituted 40 percent or more of the total wet fish landings. Because of its high commercial value it can be assumed that it was preferentially sought by the trawlers from these ports. Under such conditions the catch data for tarakihi alone can be related to the total trawl fishing effort (Ketchen 1964). In the Wellington fishing fleet steam trawlers and motor trawlers have operated side by side for a long time, but their landings have not been listed separately in the Annual Reports.

TABLE 9: Quantities of tarakihi landed at the main ports and their percentages of the total landings at those ports

	1936		1940		1945		1950		1955		1960		1965		1969	
Port	cwt	%	cwt	%	cwt	%	cwt	%	cwt	%	cwt	%	cwt	%	cwt	%
Auckland	24,966	16	13,185	11	23,965	20	30,680	25	30,873	27	16,851	13	10,453	7	4,205	3
Tauranga	342	9	300	1	1,289	17	9,167	61	8,964	46	8,889	35	12,568	35	8,528	18
Gisborne	194	5	3,008	45	6,308	77	8,939	67	13,863	66	28,304	78	36,011	60	24,127	37
Napier	13	0*	3,138	19	9,744	51	14,043	58	9,079	41	15,608	43	16,654	36	6,030	11
Wellington	21,068	46	12,138	35	16,857	53	27,027	57	29,191	61	25,543	53	16,439	40	9,930	39
Lyttelton	5,578	37	5,050	44	4,840	42	5,984	36	6,521	30	5,419	29	7,686	28	2,936	26
Timaru	0	0	108	1	44	0*	2,009	9	3,373	11	6,575	15	10,447	20	2,748	8
Greymouth	47	3	21	1	Unknown		1,161	30	163	5	561	11	530	8	2,885	46
Westport	1	0*	0	0*	8	0*	817	28	74	3	363	8	100	2	18	2
Nelson	0	0	0	0	3	0*	7	0*	56	0*	214	1	128	1	1,976	6

* Small percentage rounded off to zero.

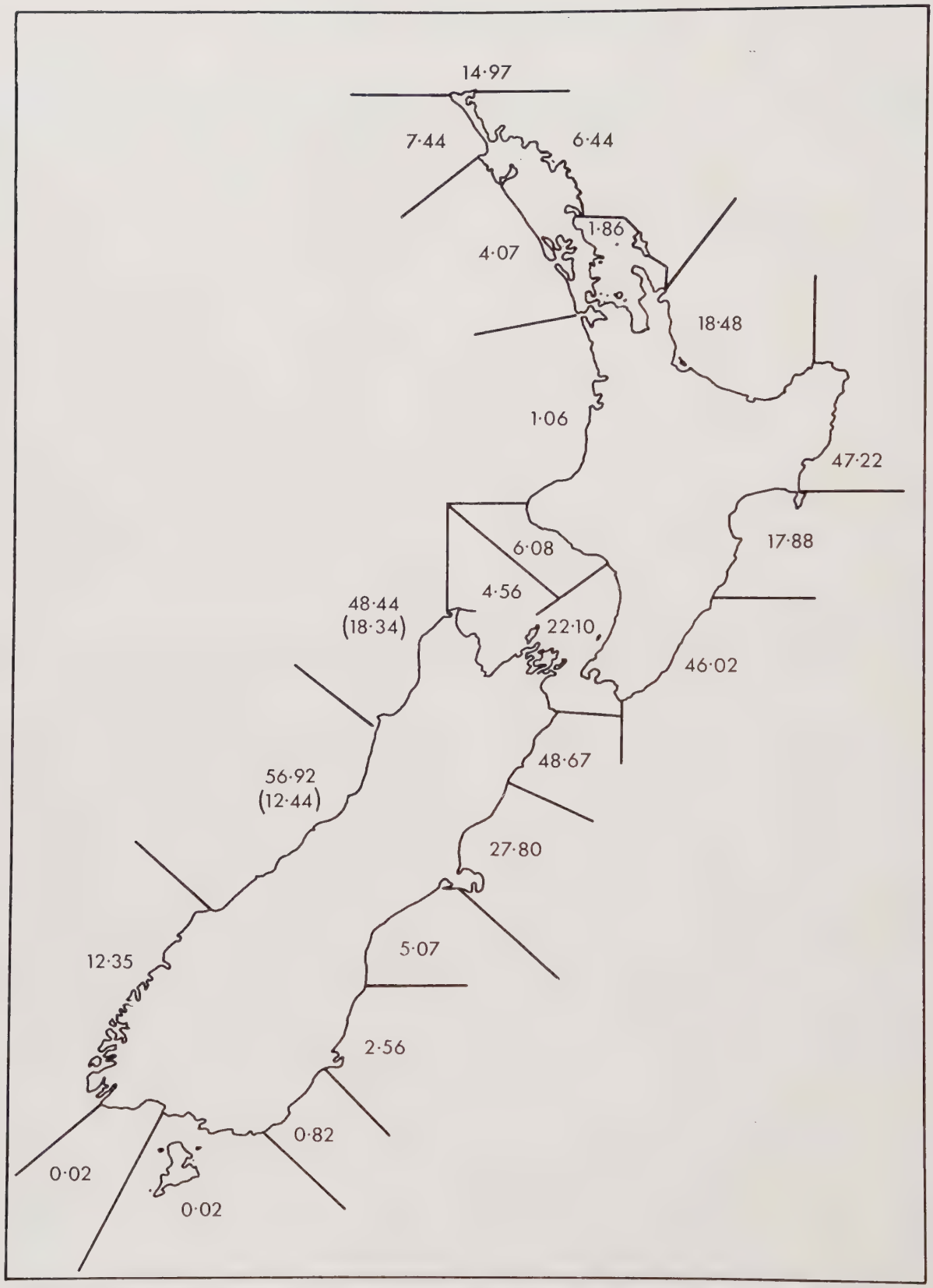

Fig. 8: The percentage of tarakihi in the total wet fish landings in each statistical area in 1967. The figures in parentheses are the landings for areas 21 and 22 in 1966.

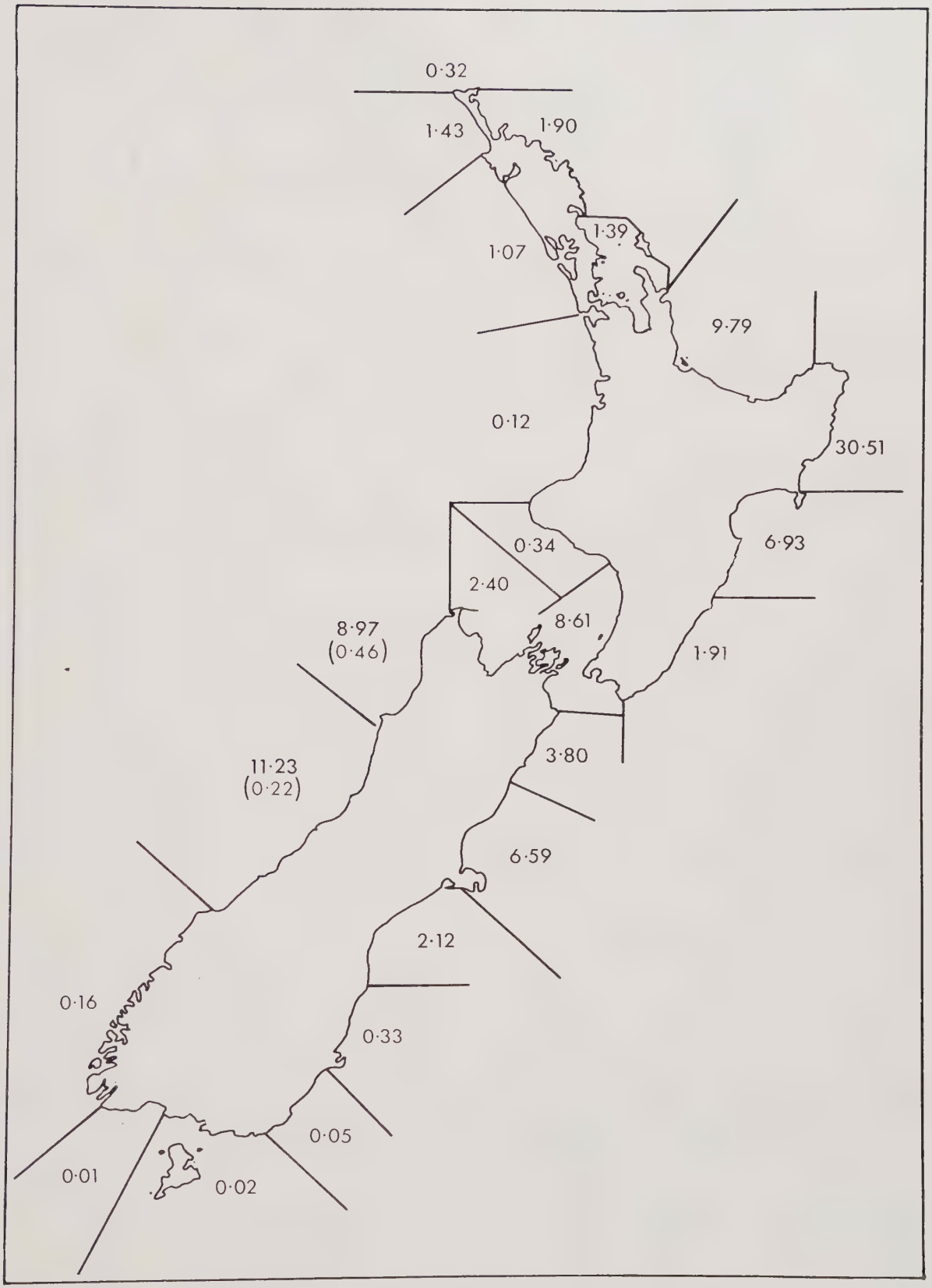

Fig. 9: The percentage of the total New Zealand tara kihi landings caught in each statistical area in 1967. The figures in parentheses are the landings for areas 21 and 22 in 1966.

TABLE 10: Total tarakihi landings for the whole of New Zealand, 1963-69

Year	Total catch (cwt)	Total catch (landings at Nelson excluded) (cwt)
1963	112,182	111,881
1964	115,573	115,274
1965	118,367	118,239
1966	122,682	122,682
1967	124,555	91,030
1968	110,312	76,547
1969	71,007	69,040

The Wellington figures were therefore analysed in terms of "unit motor trawlers". One steam trawler was considered equivalent to six unit motor trawlers, because since 1948 the annual catch/effort of steam trawlers for all wet fish as a whole has been on average six to seven times as large as that of motor trawlers.

If the large tarakihi catches made in 1967 and 1968 in the previously unexploited areas 21 and 22 and landed at Nelson are ignored, it is apparent that the major decrease in the total annual tarakihi landings in 1969 reflects a decline of the older tarakihi fisheries that started in 1967 (Table 10). This decline was not a local phenomenon, but occurred in all important traditional tarakihi fishing areas (Table 9).

The decrease in the tarakihi landings at Lyttelton and Timaru coincided with a reduction of the trawl fishing effort on the east coast of the South Island. This reduction was due to the fact that from 1966 onward many trawlers and trawl fishermen from ports in the South Island were attracted to the suddenly developing Chatham Islands rock lobster fishery (Kensler 1969, New Zealand Fishing Industry Board 1970). Between 1965 and 1969 the Lyttelton trawler fleet decreased from 21 to 16 boats and the Timaru fleet from 30 to 22 (Table 3). At Lyttelton the reduction of the fleet was accompanied by a decrease in the catch/trawler-year of all species simultaneously (Table 11); the proportion of tarakihi in the landings remained unchanged.

TABLE 11: Total wet fish catch/effort of motor trawlers (in hundredweight/trawler-year)

Port	1965	1969
Tauranga	4,451	4,697
Gisborne	2,983	2,821
Napier	2,895	2,922
Lyttelton	1,300	714
Timaru	1,726	1,562

At Timaru the decrease in the number of trawlers was accompanied by a considerable change in the species composition of the trawl catches. Though the total wet fish catch/trawler-year remained similar (Table 11), the catch/trawler-year of red gurnard and tarakihi decreased sharply; these two species were replaced in the landings by red cod.

The number of motor trawlers registered at Tauranga, Gisborne, and Napier increased between 1965 and 1969, which indicated an increase in the trawl fishing effort in the Bay of Plenty, East Cape area, and Hawke Bay (areas 4, 5, and 6). In spite of this, the tarakihi catches declined considerably, though the total wet fish catch/trawler-year remained the same. The decline in the tarakihi landings was partly offset by a large increase in the landings of commercially less valuable categories (Tables 11 and 12).

The data for Gisborne (Fig. 10) refer to catch and effort in the East Cape area. The exceptionally high peak in the tarakihi catch/trawler-year in 1945–46 seems anomalous and may be due to unknown errors in the data. If this peak is ignored, the main features of the data are an increase in the fishing effort from 5 trawler-years in 1940 to 23 in 1969 and a rapid increase in the tarakihi catch/effort until 1960, followed by an even more rapid decline. This decline coincided with an acceleration of the growth of the Gisborne trawler fleet. Between 1960 and 1969 the number of trawlers registered at Gisborne increased from 9 to 23, but the tarakihi catch/effort was reduced from 3,145 to 1,049 cwt/trawler-year.

In the Napier tarakihi fishery, which is principally carried out in the Hawke Bay area, the trawl fishing effort remained almost unchanged from 1950 to 1965, while the catch/trawler-year fluctuated around 800 cwt/trawler-year (Fig. 11). From 1965 to 1969 the fleet increased from 16 to 19 (with a peak of 24

TABLE 12: Percentual species composition of wet fish landings at Tauranga, Gisborne, and Napier (major species only), referring to the trawl fishery in the Bay of Plenty (area 4), East Cape area (area 5), and Hawke Bay (area 6) respectively (the figures for southern kingfish include small amounts of yellowtail and southern hake).

	Tauranga			Gisborne			Napier		
Category	1960	1965	1969	1960	1965	1969	1960	1965	1969
"Bait", barracouta, and trevally	13	13	21	3	7	13	8	12	22
Red gurnard	2	5	3	7	8	6	15	18	15
Snapper	45	37	44	7	10	15	14	8	10
Southern kingfish	0*	1	3	0*	1	3	2	3	9
Warehou	0	0	0	0	0	0	0*	0*	2
Tarakihi	35	35	18	78	60	37	43	36	11

* Small percentage rounded off to zero.

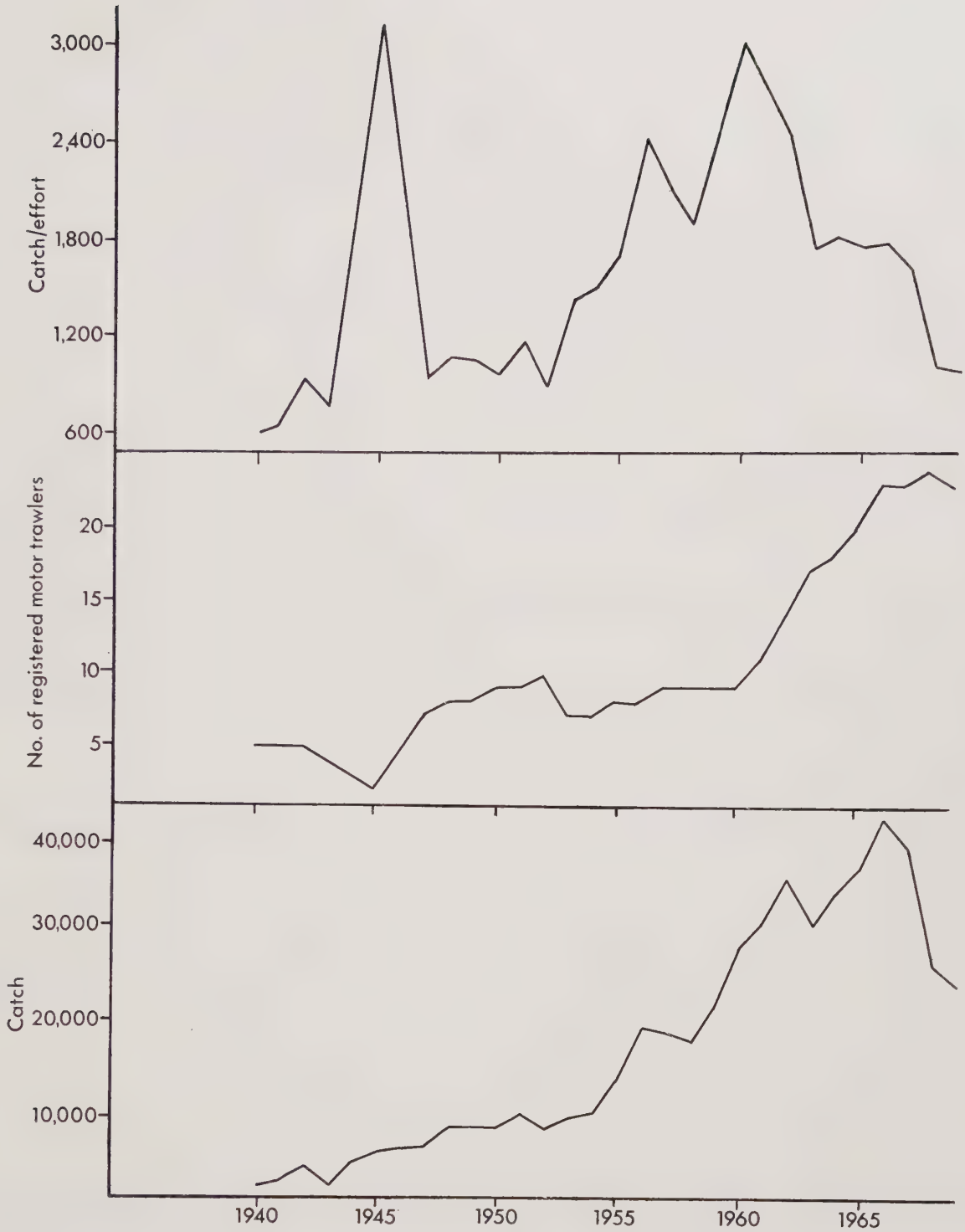

Fig. 10: The tarakihi catch (in hundredweight), effort (as indicated by the number of registered boats), and catch/effort (in hundredweight/trawler-year) of the motor trawlers registered at Gisborne.

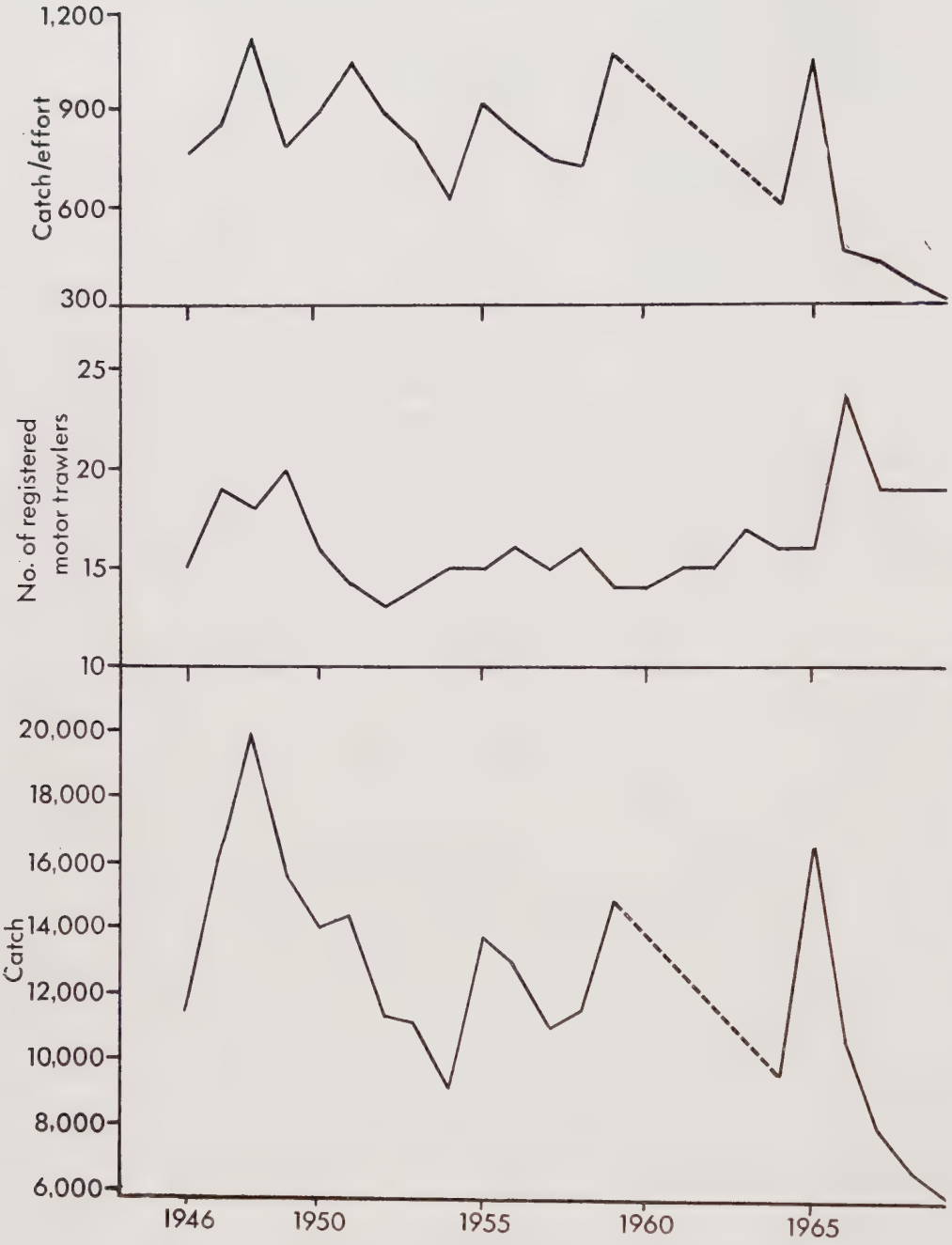

Fig. 11: The tarakihi catch (in hundredweight), effort (as indicated by the number of registered boats), and catch/effort (in hundredweight/trawler-year) of the motor trawlers registered at Napier. Catch figures for 1960-64 have been excluded because of the presence of one steam trawler.

in 1966), but there was a rapid decline in the catch/effort to 320 cwt/trawler-year in 1969.

At Wellington there was a major decrease in the tarakihi catch/trawler-year during 1940–44, when there was a reduction in the time spent annually at sea by the steam trawlers owing to a shortage of manpower and equipment resulting from the war (Fig. 12). There was a rapid recovery in 1945, a steep decline in 1953–54, and a general increase from 1955 onward. These features of the 1953–69 data probably reflect inadequacies in the unit of effort used. The decrease in 1953–54 represented a temporary downward fluctuation in the general performance of steam trawlers that was not part of a long-term trend (compare with Fig. 4). The increase after 1954 coincided with the gradual replacement of steam trawling by motor trawling and probably reflects the previously noted increase of the absolute fishing power of the New Zealand motor trawlers in general (see page 19).

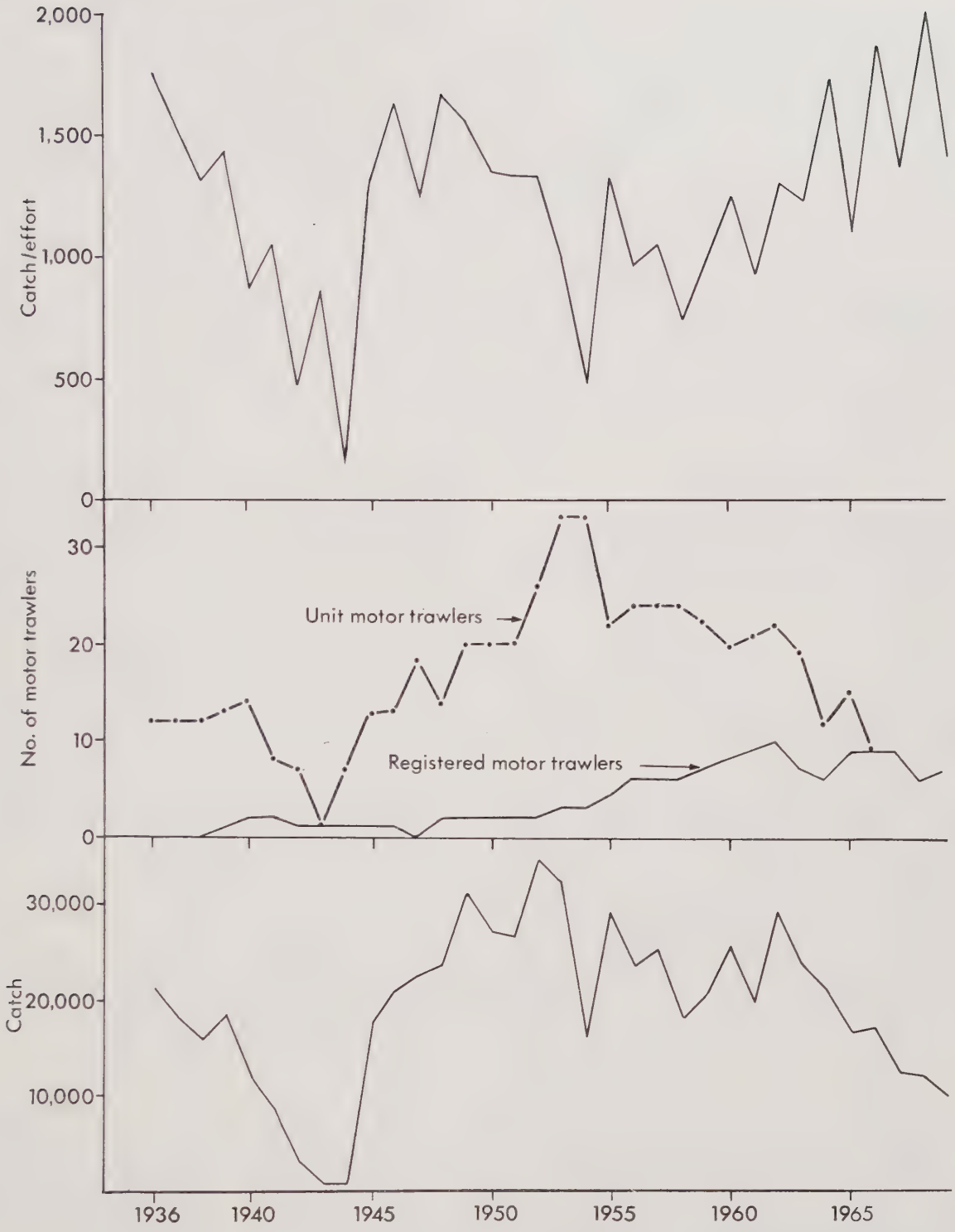

Fig. 12: The tarakihi catch (in hundredweight), effort, and catch/effort (in hundredweight/unit motor trawler-year) of the steam and motor trawlers registered at Wellington. One steam trawler is equivalent to 6 unit motor trawlers, and 1 motor trawler equals 1 unit motor trawler.

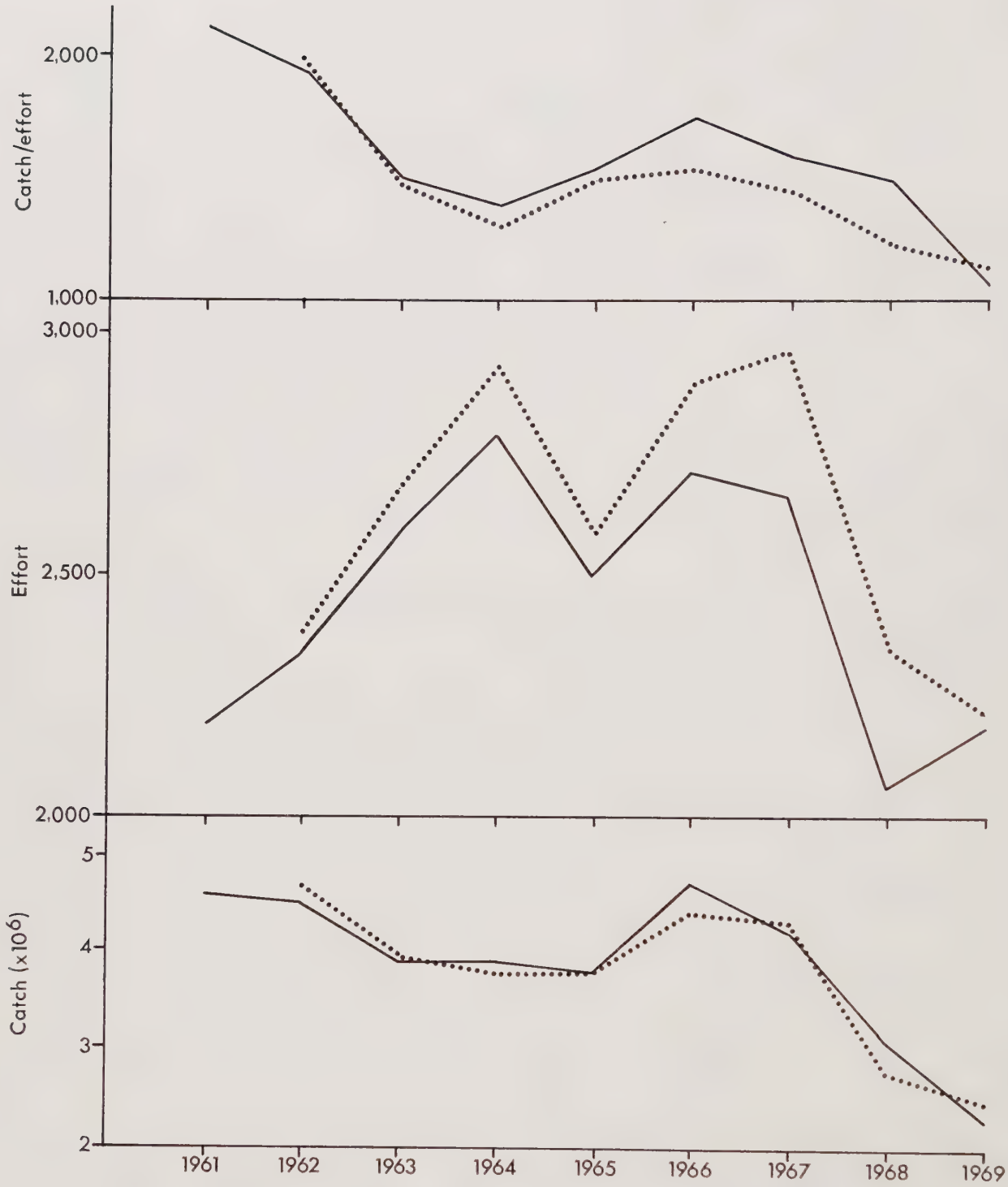

Fig. 13: The catch (in pounds), effort (in motor trawler-days-at-sea), and catch/effort (in pounds/motor trawler-day-at-sea) in the tarakihi fishery in area 5, 1961-69. Solid line: data summary by the author. Broken line: data summary by the New Zealand Marine Department.

CATCH/EFFORT ANALYSIS OF THE DETAILED STATISTICS

The detailed statistics show little correlation between catch/trawler-day-at-sea and vessel size in the fishery for tarakihi on the east coast of the North Island. The trawler-day-at-sea was therefore chosen as the best unit of effort applicable to the tarakihi fishery in this region.

In this section "trawler" stands for "motor trawler", because the data discussed below refer to the fishery by motor trawlers only.

In addition to the author's summaries of the detailed statistics for area 5, summaries prepared independently by the New Zealand Marine Department were also available. A catch/effort analysis of both sets of data gave very similar results (Fig. 13, Table 13). The catch/trawler-day-at-sea decreased between 1961 and 1963 from 2,107 to 1,495 lb/day, increased slightly until 1966, and then decreased again more slowly to 1,074 lb/day in 1969. The annual fishing effort in the area increased from 2,006 trawler-days in 1961 to 2,793 in 1964, then decreased to 2,185 in 1969 (figures quoted from author's summaries).

The monthly tarakihi catch/trawler-day-at-sea for area 5 over 1962–69 was generally highest in autumn (March-May) and spring (September-November) (Fig. 14). The autumn peak coincided with the spawning season of the tarakihi in the East Cape area (McKenzie 1961, Tong 1972), and represented presumably a fishery on spawning concentrations. In some years (1962, 1965–67) there was a tendency toward a third peak in winter (June-August), but this was not a regular feature of the data. The main tarakihi fishing seasons in the East Cape area are therefore March-April and September-November.

For area 6 the major feature of the catch/effort data (derived from the summaries by the New Zealand Marine Department) is a very steep decline from 857 lb/day in 1965 to 282 lb/day in 1969. The fishing effort increased from 1,465 trawler-days in 1961 to 2,199 in 1968 and then decreased to 1,911 in 1969 (Fig. 15, Table 13). The monthly catch/trawler-day-at-sea from 1962 to 1969 was irregular and did not show consistent seasonal fluctuations.

TABLE 13: Trawl fishing effort (in trawler-days-at-sea) and tarakihi catch/effort (in pounds/trawler-day-at-sea) in areas 5 and 6, 1961-69

	Year	Effort	Catch (lb)	Catch/ effort
Area 5 (author's summaries)	1961	2,006	4,610,243	2,107
	1962	2,342	4,513,397	1,927
	1963	2,590	3,872,399	1,495
	1964	2,793	3,855,910	1,381
	1965	2,497	3,812,577	1,527
	1966	2,710	4,713,602	1,739
	1967	2,662	4,199,376	1,578
	1968	2,070	3,079,509	1,488
	1969	2,185	2,346,539	1,074
Area 5 (summaries by Marine Department; none available for 1961)	1962	2,372	4,690,353	1,977
	1963	2,679	3,963,449	1,479
	1964	2,932	3,811,538	1,300
	1965	2,593	3,825,943	1,475
	1966	2,890	4,413,301	1,527
	1967	2,960	4,257,844	1,438
	1968	2,352	2,887,599	1,228
	1969	2,217	2,494,906	1,125
Area 6 (summaries by Marine Department)	1961	1,465	1,032,573	705
	1962	1,550	708,173	457
	1963	1,435	785,416	547
	1964	1,861	886,180	476
	1965	1,988	1,702,654	857
	1966	1,955	1,212,352	620
	1967	1,752	656,913	375
	1968	2,199	614,034	279
	1969	1,911	538,488	282

DISCUSSION

Since 1967 the annual tarakihi landings have decreased for all the important traditional tarakihi fishing areas: the Bay of Plenty, the East Cape area, Hawke Bay, Cook Strait, Pegasus Bay, and the Canterbury Bight.

The Bay of Plenty (Area 4)

In this area, despite the drop in tarakihi landings, the total wet fish catch per trawler-year has remained the same, with the remainder made up of snapper and trevally, which are caught in shallower water (Tong and Elder 1968). The change in composition of the catches therefore reflects a shift of the fishing effort toward shallower grounds. Strong year classes of snapper have occurred in recent years in the Bay of Plenty, in combination with exceptionally large and dense spawning concentrations, and the fish trade in this region at present favours snapper and trevally (L. J. Paul, pers. comm.). The shift of the trawl fishing effort may be due primarily to these factors rather than to a decrease in the abundance of the tarakihi.

The East Cape Area (Area 5)

The detailed statistical data for the East Cape area indicate that between 1961 and 1969 there was no relationship between the absolute tarakihi fishing power of trawlers and their length and bhp; in other words, larger trawlers did not catch more tarakihi per day-at-sea than the smaller vessels.

A comparison between the Annual Reports and the detailed statistics for 1961–69 shows that the increase of the Gisborne trawler fleet over those years does not adequately reflect the pattern of the actual fishing effort in the area. The number of

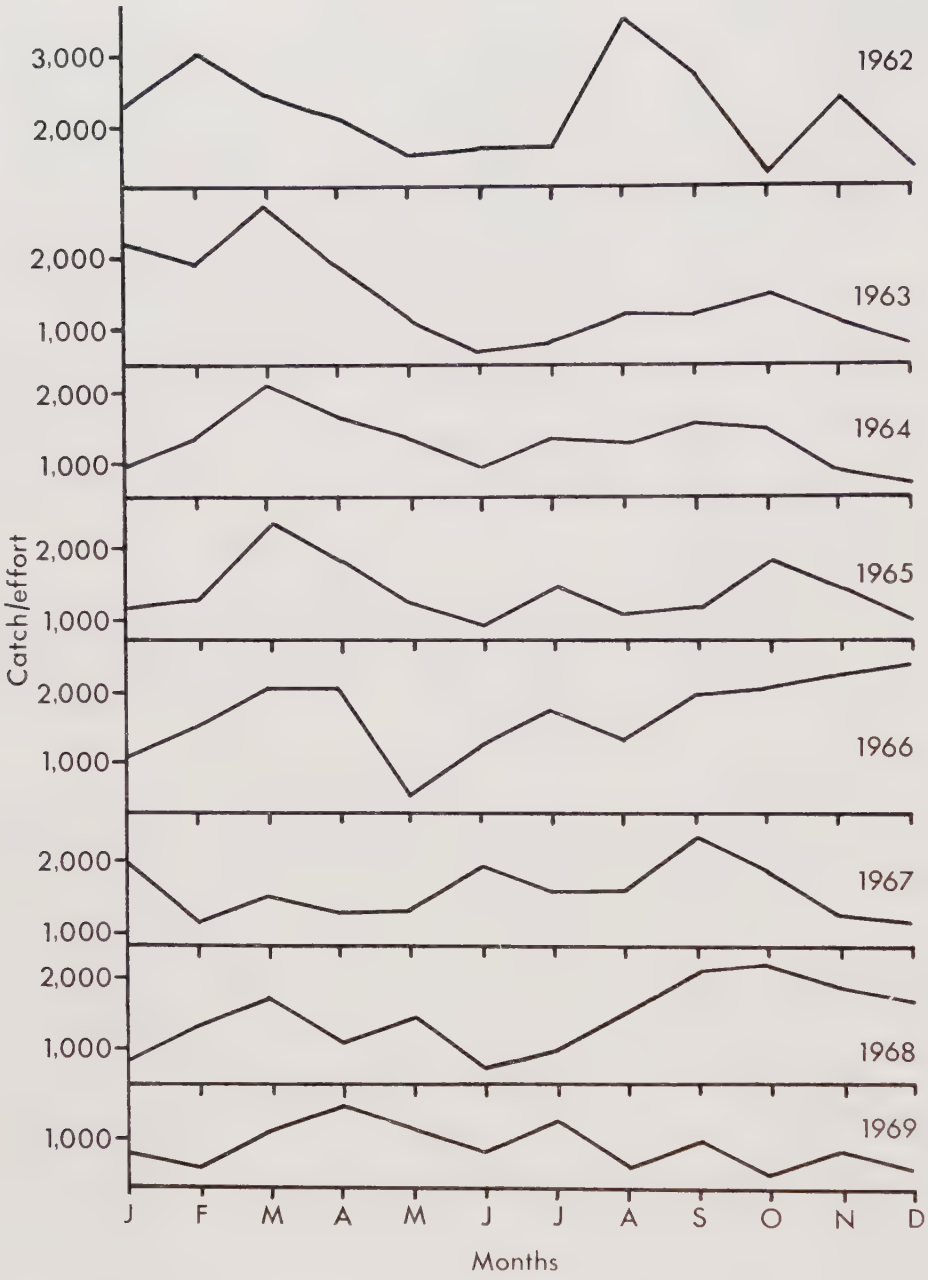

Fig. 14: The monthly tarakihi catch/effort (in pounds trawler-day-at-sea) in area 5, 1962-69. From data summary by the New Zealand Marine Department.

trawlers at Gisborne increased from 11 in 1961 to 23 in 1966 and has since remained the same. The annual effort in terms of trawler-days-at-sea in area 5 increased rapidly from 2,006 in 1961 to 2,793 in 1964, stayed about the same until 1967, and then decreased in 1968 and 1969 to values similar to that for 1961 (2,070 in 1968 and 2,185 in 1969). This discrepancy between the two measures of effort is due to the fact that up to 1964 fishing fleets from other distant ports, notably Auckland, contributed much to the fishing effort in area 5. The decrease of the fishing effort in terms of trawler-days-at-sea between 1964 and 1967 reflects the withdrawal of the Auckland, Tauranga, and Napier trawlers from the area. Since 1967 the Gisborne trawlers themselves have also reduced their activity in the area; though the number of boats remained similar, the effort in terms of trawler-days-at-sea decreased considerably.

However, both the Annual Reports and the detailed statistics show clearly that most of the decline in the catch rate occurred between 1960 and 1964. According to the detailed statistics, it declined sharply from 2,107 lb/day-at-sea in 1961 to 1,381 lb/day-at-sea in 1964, but since then there

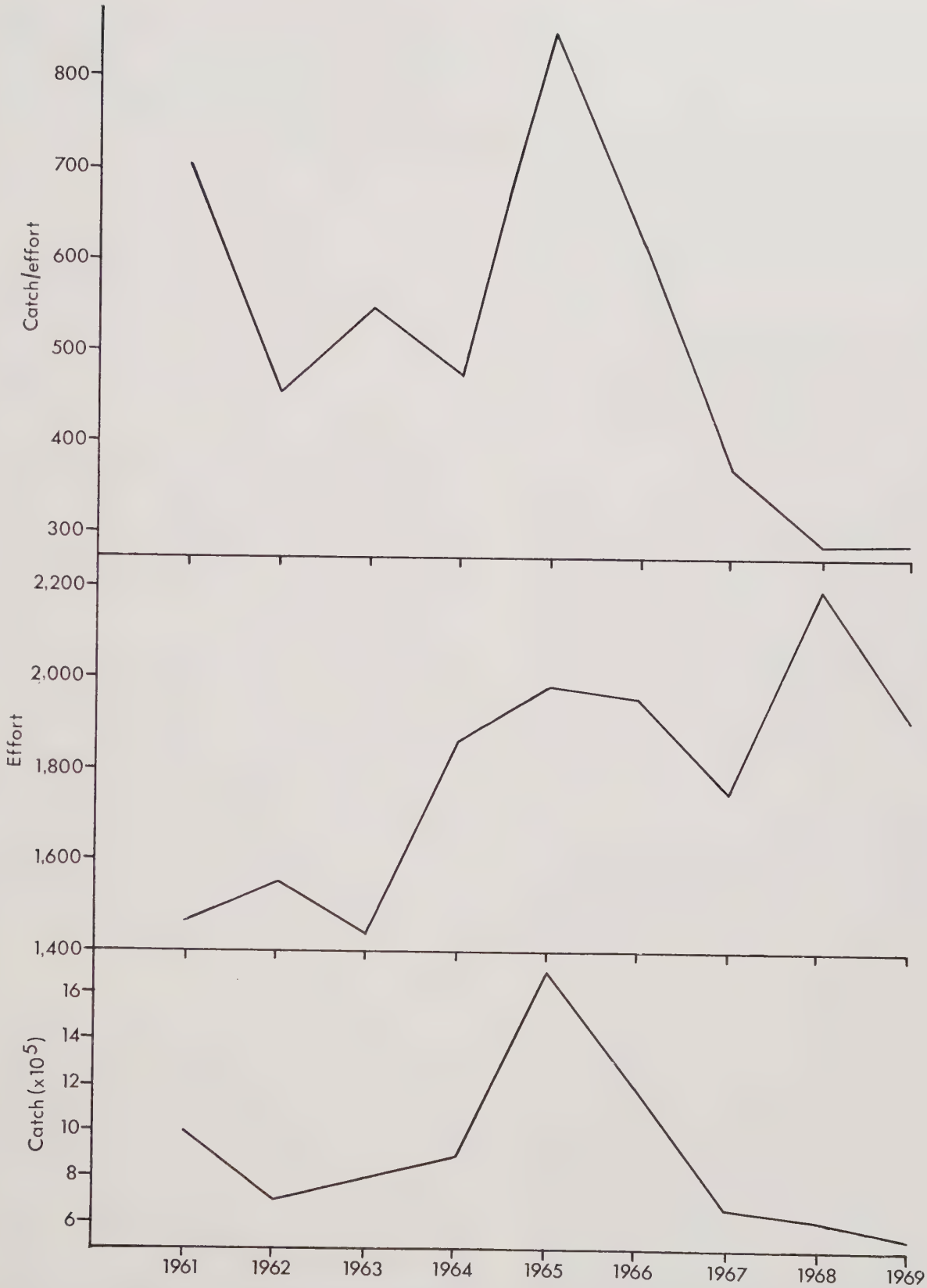

Fig. 15: The catch (in pounds), effort (in trawler-days-at-sea), and catch/effort (in pounds/trawler-day-at-sea) in the tarakihi fishery in area 6, 1961-69. Figures for 1961 from data summary by the author. Figures for 1962-69 from data summary by the New Zealand Marine Department.

has been only a small decrease to 1,074 lb/day-at-sea in 1969.

Because the East Cape area is a traditional tarakihi fishing area, the decrease of the catch/trawler-day-at-sea in 1960–64 reflects a decline in the abundance of this species. The decrease in the tarakihi landings has been offset by larger landings of snapper, trevally, and barracouta, which indicates a shift in the spatial distribution of the trawl fishing effort, as occurred in the Bay of Plenty. However, such a shift in the East Cape area would be a reaction to the shortage of tarakihi on the traditional fishing grounds rather than the result of a choice of other species. Recent observations have shown that the decrease in the stock size of the East Cape tarakihi is of an amount to be expected as a result of increasing mortality rates in an expanding fishery and is not necessarily the result of a decrease in recruitment (Vooren 1973).

The trawlers operating in the East Cape area showed a pronounced positive correlation between overall length and both the trevally catch/trawler-day-at-sea and the combined percentage of trevally and barracouta in the landings. The considerable increase in mean boat length and bhp of the Gisborne trawlers between 1956 and 1968 (see Table 4) suggests that in area 5 there is a tendency toward larger, more powerful trawlers landing bulk catches of lower-priced fish. This in itself may be a response to a decrease in the abundance of tarakihi in the East Cape area.

Hawke Bay (Area 6)

For this region there are again discrepancies between the estimates of the fishing effort from the Annual Reports and the detailed statistics. The small increase in the number of Napier trawlers from 15 in 1961 to 16 in 1965 understates an increase of 35 percent in the fishing effort in terms of trawler-days-at-sea from 1,465 in 1961 to 1,988 in 1965. The sudden increase in the number of trawlers from 16 to 24 in 1966, followed by a more gradual decrease to 19 in the following years, is not reflected in the number of trawler-days-at-sea; from 1965 onward this has fluctuated around a steady level of 2,000. However, both the Annual Reports and the detailed statistics show the same general pattern: a decrease in the catch rate in 1961–64, followed by an increase in 1965, followed by a large decrease in the subsequent years from 857 lb/day-at-sea in 1965 to 282 lb/day-at-sea in 1969. The decrease in 1961–64 equals fluctuations that have occurred in 1949, 1954, and 1957–60. The decline of the tarakihi catch and catch rate from 1965 onward was offset by increased landings of less valuable types of fish (trevally, warehou, and "bait" for the rock-lobster fishery). This suggests that the recent decline in the tarakihi catch rate reflects a decrease in the abundance of this species, as a result of which the fleet diverted its effort to other fish stocks.

Cook Strait (Areas 8 and 13)

The data for Wellington show an increase in the catch per unit trawler-year from 1958 onward, which indicates an increase in the absolute tarakihi fishing power of the motor trawlers. It is theoretically possible that a decline in the abundance of the tarakihi has occurred during the same period, masked by a very much greater increase in the absolute fishing power, but the increase in the catch rate is so steep (750 cwt/trawler-year in 1958 and 1,420 in 1969) that this is not likely. The data therefore indicate that in Cook Strait the abundance of the tarakihi has not changed much during the period under study. The decrease in the tarakihi landings at Wellington in recent years is a result of a reduction of the fishing effort only.

Pegasus Bay (Area 14)

At Lyttelton, the main fishing port for this area, the number of registered trawlers decreased in 1965–69 from 21 to 16, and this was accompanied by a decrease in catch/trawler-year for all major species simultaneously, including the tarakihi; the proportion of this species in the landings remained the same. This suggests that after the departure of a large number of boats and fishermen to the Chatham Islands rock lobster fishery the overall efficiency of the remaining trawler fleet was much reduced. Thus the decline of the tarakihi landings from Pegasus Bay was due to a substantial decrease in the fishing effort in this area.

Canterbury Bight (Area 15)

At the main fishing port, Timaru, the number of motor trawlers decreased from 30 in 1965 to 22 in 1969, which shows a large decrease in the trawl fishing effort in this area. At the same time the tarakihi and red gurnard catch/trawler-year decreased sharply, and the landings of red cod rose. This may indicate a simultaneous decrease in the abundance of tarakihi and red gurnard, but may also be a consequence of the departure of experienced fishermen to the Chatham Islands fishery, which resulted in a change in the operating pattern of the Timaru trawler fleet. It must also be considered that large foreign trawlers, mainly from Japan, but also from the U.S.S.R., have fished on off-shore grounds in the Canterbury Bight since 1967.

Detailed statistics on the catches by these ships are not available. Figures supplied by Mr I. Ikeda show that the catches by the Japanese trawlers consisted mainly of barracouta and horse mackerel. The proportions of tarakihi and red gurnard were small, but they represented considerable quantities in comparison with the catches by the trawlers from Timaru. In 1968 the Japanese trawlers caught 1,575 cwt of tarakihi and 2,874 cwt of red gurnard, and the landings of these species at Timaru were 3,260 cwt and 4,441 cwt respectively. Thus, it is possible that both the tarakihi and the red gurnard have decreased in abundance in the Canterbury Bight because of the additional fishing by foreign vessels.

General Conclusions

In the East Cape area and Hawke Bay the tarakihi has clearly declined in abundance since 1960 and 1964 respectively, and this decline may have resulted from an increase in the fishing effort. Further detailed research on the basic population characteristics of the tarakihi in these areas is necessary before conclusions can be drawn and proposals for management of the fishing effort can be made. In the meantime the fishing fleet in each of these areas is reacting to the decline of the tarakihi stocks in its own way by diverting its effort to other species, including species of less commercial value such as trevally.

A major weakness of the present statistical information is that each of the statistical areas is very large, comprising up to 150 miles of coastline and including all depths from shallow in-shore waters down to beyond the edge of the continental shelf. Shifts in the spatial distribution of the fishing effort must occur within these large areas, but can be inferred only when there are changes in the species composition of the landings. A shift of the fishing effort from one stock to another of the same species within the statistical area cannot be detected under the present system.

Owing to this feature of the data, the present information on the Bay of Plenty and the Canterbury Bight is inconclusive. It is fairly certain that there was a shift of the fishing effort from deep to shallower water in the former area, but it cannot be shown whether this shift was a reaction to a decline in numbers of the tarakihi in the deeper water, to an increase of snapper in the shallower water, or to both.

The data for Gisborne (page 30) and Napier (page 32) show that discrepancies can occur between trends in the rough index of abundance given by the catch/trawler-year and the more refined index provided by the catch/trawler-day-at-sea. Nevertheless, the same data show that a major fluctuation in the abundance of a dominant species is reflected equally clearly by both indices. The tarakihi catch/trawler-year of the Wellington and Lyttelton trawler fleets does not show such a fluctuation, and this indicates that the abundance of the tarakihi in Cook Strait and Pegasus Bay as a whole has not declined. It is again possible that, within these large areas, local stocks have declined unnoticed, which has forced the fleet to move to other tarakihi fishing grounds within the same general area.

A more refined statistical system, which gives detailed information on time and place of catch and effort and on the quantity and quality of the effort itself in terms of operating rate and size and type of gear used, is obviously necessary. Furthermore, research on the tarakihi populations in the Bay of Plenty, the East Cape area, and Hawke Bay is needed to evaluate the biological significance of the decline in abundance in these areas.

SUMMARY

Most of the New Zealand wet fish catch, including almost the entire tarakihi catch, is landed by small diesel-powered motor trawlers. The trawler fleet has increased from 52 boats in 1936 to 324 boats in 1969 (excluding boats at the Chatham Islands). The average size and brake horsepower (bhp) of these trawlers has increased continuously from about 40 ft (12 m), 16 gross tons, and 40 bhp in 1946 to 50 ft (15 m), 30 gross tons, and 150 bhp in 1966, and both size and power of the boats are still increasing. The boats have crews of 1 to 3 men, make mostly short fishing trips of 1 to 3 days near their home ports, and spend on average 100 to 150 days at sea a year. The trawler fleet of Auckland is an exception in that these boats make fishing trips of 4 to 7 days.

For all wet fish species taken together, there is a positive linear relationship between the relative fishing power of the New Zealand trawlers and their overall length, gross tonnage, and bhp. These three vessel parameters are closely correlated, and each can therefore be used as a measure of relative fishing power. The values recorded for bhp are those specified by the makers of the engines and are not based on periodic measurements. Gross tonnage is not yet measured for all fishing boats. The overall length is known for each boat, can be measured easily and accurately, and is therefore the best and most convenient measure of relative fishing power available at present. By defining the relative fishing power of a 50-ft trawler as equal to 1, the following equation was found for the East Cape area:

$$RP = -0.9189 + 0.0384\ L$$

where RP is relative fishing power and L is length in feet. The same relationship appears to hold for Pegasus Bay and the Canterbury Bight and may apply to New Zealand trawlers in general.

The continuous increase in the annual wet fish landings can be largely accounted for by the increase in the number of trawlers and the simultaneous increase in boat size; though the landed catch per trawler-year was 830 cwt in 1946 and 1,640 cwt in 1966, the landed catch per 50-ft trawler-year was in these years 1,437 cwt and 1,774 cwt respectively.

It should be noted, however, that there is still considerable variation in the catches within and between fishing areas which cannot be explained by variations in boat size and bhp and which must be due to variables not measured at present. For instance, there is hardly any information on the gear used in the New Zealand trawl fishery, and there is a great need for research on this point.

The main traditional tarakihi fishing areas are, in order of importance, the East Cape area, the Bay of Plenty, Cook Strait, Hawke Bay, Pegasus Bay, and the Canterbury Bight, though the exploitation of good tarakihi fishing grounds off Kaikoura Peninsula and the west coast of the South Island has begun in recent years. Since 1967 the catches in all traditional tarakihi fishing areas have declined. The decline in Cook Strait and Pegasus Bay appears to be due to a reduction of the fishing effort rather than to a decline of the tarakihi stocks. The data for the Canterbury Bight and the Bay of Plenty are inconclusive: in the latter area there has been a shift in the fishing effort from the deeper grounds, where the tarakihi are usually caught, to the shallower grounds, where snapper and trevally are abundant, but it is not clear whether this shift is a result of a decline of the tarakihi stock or of a choice in favour of catches of snapper and trevally. In the East Cape area the abundance of tarakihi declined strongly between 1960 and 1964. However, the catch per unit effort has not declined appreciably since 1964, so that the stock abundance does not appear to be decreasing much further in this area. The data for Hawke Bay show a sharp decline in the abundance of the tarakihi from 1965 onward. Recent observations in the East Cape area have suggested that the decline there is such as can be expected in a developing fishery and is not necessarily due to a decrease in recruitment.

No positive correlation was found between the tarakihi catches and the size and bhp of trawlers in the East Cape area, but a pronounced relationship was apparent between these vessel parameters and the catches of trevally and barracouta, both species of low commercial value. There appears to be a trend in the East Cape area from a fishery where small trawlers land small quantities of highly priced fish such as tarakihi to a fishery where larger trawlers land less valuable kinds of fish in bulk. This trend may be a reaction to the lower abundance of tarakihi in recent years, which has forced the fleet to divert its effort to other fish species present in the East Cape area.

The statistical data on catch and effort as they are collected at present provide useful information on regions where one species is strongly dominant in the fishery over a large geographical area. However, in most areas the trawl fishery exploits a great variety of species, and the available statistical data are not detailed enough to deal with these fisheries. A statistical scheme is needed which provides more detailed information on the time and place of catch and effort and on the quantity and quality of the fishing effort itself in terms of operating rate and the type and dimensions of the gear used.

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APPENDIX 1: DEFINITIONS

The terms and symbols used in this bulletin are largely those proposed by Traung and Gulland (1957), but they are defined here so that they apply specifically to the fishery with the otter trawl in New Zealand waters. Terms relating to distribution and abundance refer only to fish of commercial size and to the portion of the stocks that can be fished by trawl, and trawling refers to fishing with the otter trawl only.

A **unit stock**, or briefly **stock**, of fish is "a population in which the vital parameters of recruitment, growth, and mortality are homogeneous" (Cushing 1968, page 40), and which responds as one single unit to factors which affect these parameters. The catch data that are analysed in this bulletin have the dimension weight; **abundance** therefore stands for the total weight of the fish stock. The **stock density** is the quotient of the abundance and the size of the area occupied by the stock.

The fishery is done by **fishing units**, each consisting of a boat, a crew, and a set of trawl gear. A fishing unit does a series of discrete **unit operations**, for instance, trawl hauls. A **standard unit operation** is a trawl haul of unit duration, for example, 1 hour. The **operating rate** of a fishing unit is the average number of standard unit operations performed per unit time spent at sea, and the **performance** over a given period is the annual catch per unit time spent at sea. Monthly performance and annual performance are the performance averaged over a month and a year respectively. The **fishing time** of a fishing unit is the sum of the duration of the unit operations over a given period and in trawling is equivalent to the number of standard unit operations done during the period.

According to a principle stated by Beverton and Holt (1957, page 172), fishing effort and fishing power are defined here in terms of fishing mortality. The **absolute fishing effort** exerted by a fishing unit over a given period in a given fish stock is the proportion of the stock caught during that period. Thus, for the *i*th fishing unit,

$$E_i = \frac{C_i}{S} \qquad (1)$$

where E is absolute fishing effort, C is catch, and S is stock abundance at the beginning of the period.

For the New Zealand trawlers there is information on the time spent at sea, but not on the fishing time. Hence the **absolute fishing power** of a fishing unit with respect to a given fish stock is defined here as the average proportion of the stock caught per unit time at sea. There is a physical upper limit to the amount of fish that a given fishing unit can handle per unit time spent at sea. When abundance and stock density are so high that this limit is reached, "gear saturation" (Gulland 1956) occurs, and if the stock abundance increases further, the absolute fishing power, as defined above, decreases. This bulletin is primarily concerned with the trawl fishery for the tarakihi. This species does not appear to be subject to frequent fluctuations in abundance and stock density, and it can be safely assumed that gear saturation does not occur at the normally prevailing levels of these parameters. The only important commercial species that is known at present to fluctuate considerably in these respects is the snapper (Paul 1970).

In trawling, a unit operation amounts to the sweeping of a certain part of the bottom of the general area inhabited by a fish stock. The factors that govern the detailed distribution and movements of the important commercial fish species in New Zealand waters are as yet unknown. The general areas in which the fish occur at certain times of the year are roughly known (for example, Tong and Elder 1968) for some species, but the precise place and time of their occurrence cannot be predicted. The technique of fish searching by echo-location is poorly developed, so that within the known boundaries of the general fishing areas the fishery is a trial-and-error search process. The distribution of the unit operations over the area inhabited by the fish stock may therefore be considered as approximately random. For the *i*th fishing unit the fish density in the total swept area under these conditions is equal to the stock density:

$$\frac{N_i}{t_i \times a_i} = \frac{S}{A} \qquad (2)$$

where N is quantity of fish present in the swept area, t is fishing time (equivalent to number of standard unit operations), a is area swept per standard unit operation, and A is area inhabited by the fish stock.

The catch by the *i*th fishing unit is given by:

$$C_i = v_i \times N_i \qquad (3)$$

where v is **vulnerability** (Gulland 1956), here indicating the proportion caught of the fish present in the swept area.

From (2) and (3) follows

$$\frac{C_i}{T_i} = \frac{a_i}{A} \times v_i \times \frac{t_i}{T_i} \times S \quad (4)$$

where T is time spent at sea.

The proportion of the stock taken per unit time spent at sea is therefore wholly determined by the factors $\frac{a_i}{A}$, v_i, and $\frac{t_i}{T_i}$ (the last factor is the operating rate). Equation (4) can be written as

$$\frac{C_i}{T_i} = P_i \times S \quad (5)$$

where P is absolute fishing power.

From (1) and (5) follows

$$E_i = P_i \times T_i \quad (6)$$

so that for each fishing unit, the absolute fishing effort expended per unit time at sea is equal to its absolute fishing power.

Equation (5) implies that differences in performance between fishing units working on the same stock reflect differences in absolute fishing power: for the *i*th and *j*th fishing units

$$\frac{\frac{C_i}{T_i}}{\frac{C_j}{T_j}} = \frac{P_i}{P_j} \quad (7)$$

Usually the stock abundance is not known, so that the absolute fishing power and effort cannot be determined. A **standard fishing unit** is then defined, the unknown absolute fishing power of which is the unit of fishing power measurement. Thus, provided the standard fishing unit and the *i*th fishing unit are operating under the same conditions

$$RP_i = \frac{P_i}{P_s} \quad (8)$$

where RP_i is the relative fishing power of the *i*th fishing unit, P_i is the absolute fishing power of the *i*th fishing unit, and P_s is the absolute fishing power of the standard fishing unit.

From (8) and (5) follows

$$RP_i = \frac{\frac{C_i}{T_i}}{\frac{C_s}{T_s}} \quad (9)$$

so that the relative fishing power of a fishing unit can be measured as the ratio of its performance to the performance of the standard fishing unit operating under the same conditions.

The absolute fishing effort exerted by the standard fishing unit per unit time at sea is the unit of effort measurement. From equation (6) it follows that if RE_i is the relative fishing effort by the *i*th fishing unit,

$$RE_i = \frac{E_i}{P_s} \quad (10)$$

From (10) and (6) follows

$$RE_i = \frac{P_i}{P_s} \times T_i \quad (11)$$

From (11) and (5) follows

$$RE_i = \frac{\frac{C_i}{C_s}}{\frac{T_s}{T_s}} \quad (12)$$

so that for a fleet of n fishing units all operating on the same fish stock

$$\sum_{i=1}^{i=n} RE_i = \frac{\sum_{i=1}^{i=n} C_i}{\frac{C_s}{T_s}} \quad (13)$$

that is, the relative fishing effort of a fishing fleet can be calculated by dividing its total catch by the performance of the standard fishing unit.

From (13) and (5) it follows that

$$\frac{\sum_{i=1}^{i=n} C_i}{\sum_{i=1}^{i=n} RE_i} = P_s \times S \quad (14)$$

The quotient of catch and relative fishing effort is the **catch per unit of effort**, briefly **catch/effort**. It follows from equation (14) that changes in the catch/effort reflect changes in the stock abundance (S), in the absolute fishing power (P_s) of the standard fishing unit, or in both.

The behavioural and physical characteristics of the fish that influence the vulnerability, such as swimming speed and gear avoidance reactions, are assumed to have remained constant during the period under study. The changes in the absolute fishing power are due to changes in the fishing units only.

APPENDIX 2: CALCULATIONS

Relationships between variables were investigated by linear regression techniques described by Mode (1966) and Snedecor (1956). No attempts at curvilinear regression analysis were made; so the terms correlation and regression refer in the following text to linear analysis only. The correlation coefficient between two variables is indicated by r, and the one between more than two variables by R.

RELATIONSHIPS BETWEEN VESSEL CHARACTERISTICS

The relationship between boat length and bhp was examined for the trawlers operating in areas 5 and 14 during 1968. The correlation between the two variables was highly significant for both fleets, though the correlation was much stronger in area 14 than in area 5.

Since 1946 both the average length and bhp have increased with time (Table 4), and a relationship between age, length, and bhp was therefore expected. However, for the boats working in area 5 in 1968 no significant correlation was found between age and bhp ($r = .130$ with 26 degrees of freedom) and between age and length ($r = .340$ with 26 degrees of freedom).

The relationship between overall length and gross tonnage was determined for the trawlers working during 1966 in area 5. The correlation between the logarithms of gross tonnage and length (in feet) was significant at the 0.1 percent level ($r = .914$ with 39 degrees of freedom) and the equation was found to be

$$\log_{10} (\text{gross tonnage}) = -2.3205 + 2.2258 \log_{10} (\text{length}) \qquad (15)$$

This equation has been used for estimating the gross tonnage of boats of known length for other areas and years.

RELATIONSHIPS BETWEEN OVERALL PERFORMANCE AND VESSEL CHARACTERISTICS

The overall performance of individual trawlers was calculated by dividing the total landed wet fish catch by the number of days-at-sea, either over a calendar year (annual performance) or a month (monthly performance). The correlation was determined between performance as the dependent variable and length and bhp singly, together, and in combination with age as the independent variables. The correlation coefficients obtained were tested according to Table 22 in Arkin and Colton (1964). Where two or three independent variables were used, length was considered first, then bhp, and then age. The amount of variance accounted for by each added variable was tested against the unexplained residual variance by an F test. The significance of the F values obtained was determined from the "variance ratios" listed in Table 5 in Fisher and Yates (1953). The F values for length as a variable indicated the amount of variance explained by length alone and by bhp in so far as this variable was correlated with length. The F value for bhp was a measure of the additional amount of variance explained by bhp in so far as it varies independently from length.

The linear relationships between annual performance and the three vessel characteristics were investigated for area 5 in 1961–68 and for areas 14 and 15 in 1966–68 (Table 14, Fig. 16). All coefficients of the correlation between annual performance and length were significant except for that for area 5 in 1961.

The correlation coefficient between annual performance and length for area 5 in 1966, with the data weighted by the number of days-at-sea by each boat, was .522; in comparison the value for the unweighted data was .586. When bhp was included besides length as a second independent variable, the correlation coefficients increased considerably for area 5 in 1968 and area 15 in 1966; for all other sets of data, however, the correlations increased only slightly. Adding age as the third independent variable resulted in a further slight improvement of the correlations. The correlations found when using gross tonnage as the single independent variable for the 1966–68 data for the three areas were lower in five results and somewhat higher in four results than the corresponding correlations for length as the single independent variable.

The multiple correlation between monthly performance and the three vessel characteristics was calculated for the trawlers working in area 5 in January, March, May, July, September, and November 1966. The correlation coefficients were not significant, except for May, where $R = .781$, with 5 percent significance. In comparison the multiple correlation coefficient for the whole year was .611, which, though lower than the value for May only, was significant at the 0.1 percent level owing to a greater number of sets of values available.

TABLE 14: Relationships between total wet fish performance and vessel characteristics of motor trawlers in areas 5, 14, and 15

		r length	r tonnage	R length, bhp	F length	F bhp	R length, bhp, age	F length	F bhp	F age
Area 5	1961	.334	—	.409	3.281	1.346	—	—	—	—
	1962	.612**	—	.672**	16.036**	4.575	—	—	—	—
	1963	.560**	—	.561**	10.513**	0.030	—	—	—	—
	1964	.418*	—	.473	7.923**	1.587	—	—	—	—
	1965	.788**	—	.791**	46.419**	0.295	—	—	—	—
	1966	.586**	.493**	.588**	15.713**	0.104	.611**	16.395**	0.685	0.180
	1967	.597**	.621**	.635**	16.136**	2.064	.691**	18.504**	2.840	1.527
	1968	.643**	.691**	.751**	31.173**	3.821	.773**	27.922**	4.621*	3.113*
Area 14	1966	.711**	.659**	.734**	37.336**	2.438	.748**	37.946**	2.478	1.556
	1967	.506**	.375	.527**	10.292**	0.847	.550**	10.288**	1.047	0.788
	1968	.949**	.979**	.974**	369.987**	21.507**	.978**	410.070**	25.345**	0.005
Area 15	1966	.501**	.779**	.804**	27.680**	43.814**	.807**	27.301**	43.212**	0.474
	1967	.686**	.352	.689**	29.611**	0.223	.736**	32.852**	0.247	4.612**
	1968	.644**	.574**	.663**	14.058**	0.819	.775**	18.722**	1.090	7.302**

* 5 percent significance.
** 1 percent significance.
R: Coefficient of correlation between more than two variables.
r: Coefficient of correlation between two variables.
F: Test statistic of variance ratio test.
A dash indicates that no calculations were made.

OVERALL WET FISH CATCH/EFFORT

In view of the strong correlation between overall performance and boat length, the day-at-sea by a 50-ft trawler was chosen as the unit of effort for all wet fish as a whole. The linear regression equations of annual performance (dependent variable) on length (independent variable) were determined for area 5, years 1962–68, and areas 14 and 15, years 1966–68. By substituting 50 for the length in these equations, the total wet fish catch per day-at-sea by a 50-ft trawler, that is, the overall catch/effort, was obtained for these areas and years (Table 15).

OVERALL FISHING POWER

The slope and intersection of the regressions of overall annual performance on boat length for areas 5, 14, and 15 were divided by the corresponding relative catch/effort estimates. From equation (9) (Appendix 1) it follows that this treatment results in a linear regression equation of relative fishing power (dependent variable) on boat length (independent variable). The regressions thus obtained are listed in Table 15. Dixon's test for outliers (Dixon 1953) was applied to the values of the slopes and intersections of the regressions for area 5, years 1962–68, and showed that both the lower and upper outliers could be accepted. This means that in area 5 during the period 1962–68 there were no significant differences in the relationship between relative fishing power and boat length. The mean slope of the regression was then calculated, weighted by the sums of squares of the deviation of the boat lengths from their means. The

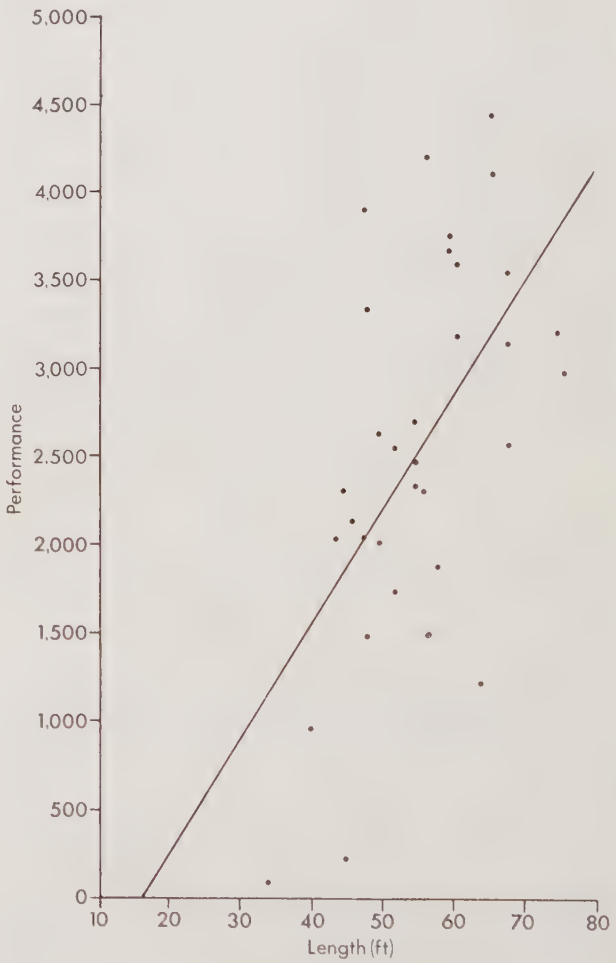

Fig. 16: The linear regression of total wet fish performance (in pounds/day-at-sea) on overall length for all motor trawlers operating in area 5 in 1966.

50-ft trawler was taken as the standard fishing unit; hence its relative fishing power by definition is 1. The mean intersection of the regression was then determined by using the known slope and substituting 1 for the relative fishing power and 50 for the boat length. The following equation was thus found, which expresses the relationship between relative fishing power (RP) and boat length (L) over the whole period:

$$RP = -0.9189 + 0.0384\ L \qquad (16)$$

Except for the data for area 14 in 1968, the coefficients of the regression equations for areas 14 and 15 fall within the range of the values observed for area 5.

RELATIONSHIP BETWEEN PERFORMANCE AND VESSEL CHARACTERISTICS IN THE TRAWL FISHERY FOR TARAKIHI

The relationship between performance and three vessel characteristics (overall length, bhp, and gross tonnage) with respect to the tarakihi fishery was investigated for the trawlers operating in area 5 over the years 1961–69. Since normally more than 40 percent of the landings from this area consist of tarakihi, the performance of a trawler was calculated by relating its landings (assumed equal to its catch) to its total fishing effort in terms of days-at-sea, according to principles outlined by Ketchen (1964).

The multiple correlation coefficients between annual tarakihi performance, boat length, and bhp in area 5 were low, but significant only for 1967 ($R = .544$, significant at the 1 percent level) and 1968 ($R = .509$, significant at the 5 percent level); for all other years they were not significant, ranging between .082 and .411. The data do not suggest that a curvilinear relationship may apply as an alternative to a straight linear one; there does not appear to be any relationship at all (Fig. 17). The correlation is not improved if the data are ignored for those boats with annual landings consisting of less than

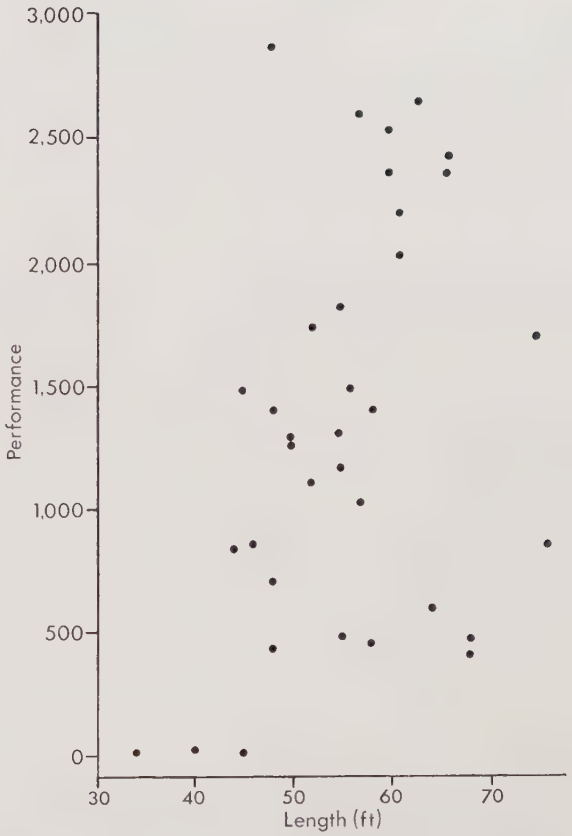

Fig. 17: The tarakihi performance (in pounds/day-at-sea) and overall length of all motor trawlers operating in area 5 in 1966.

TABLE 15: Catch/effort (in pounds/50-ft trawler-day-at-sea) and relative fishing power of motor trawlers in areas 5, 14, and 15 for total wet fish

	Year	Catch/effort ± 95% confidence limits	Equation for relative fishing power
Area 5	1962	2,276.7 ± 412.0	RP = -0.9710 + 0.0384 L
	1963	2,071.8 ± 351.0	RP = -0.4168 + 0.0283 L
	1964	2,181.0 ± 422.3	RP = -0.2875 + 0.0258 L
	1965	2,088.8 ± 310.8	RP = -1.3024 + 0.0460 L
	1966	2,182.0 ± 353.5	RP = -0.4653 + 0.0293 L
	1967	2,270.6 ± 527.5	RP = -0.9002 + 0.0380 L
	1968	1,726.2 ± 551.8	RP = -1.9123 + 0.0582 L
Area 14	1966	1,404.2 ± 201.1	RP = -1.2955 + 0.0456 L
	1967	1,235.2 ± 288.8	RP = -1.0593 + 0.0411 L
	1968	1,134.0 ± 197.6	RP = -2.4954 + 0.0699 L
Area 15	1966	1,529.9 ± 284.6	RP = -0.3524 + 0.0270 L
	1967	1,597.7 ± 187.6	RP = -0.6544 + 0.0330 L
	1968	1,270.5 ± 224.9	RP = -0.6145 + 0.0323 L

RP: Relative fishing power. L: Overall boat length in feet.

50 percent of tarakihi, as comparison between Figs. 17 and 18 shows. For 1966 the correlation between tarakihi performance and gross tonnage was also not significant ($r = .176$ with 30 degrees of freedom) and was lower than the multiple correlation coefficient between performance, length, and bhp for that year ($R = .371$ with 31 degrees of freedom).

The main tarakihi fishing season in area 5 occurs in March-April; presumably the boats are then fishing together on localised concentrations of the species under similar conditions of abundance and density. Considering those months alone did not improve the results; for March 1966, for instance, the correlation between monthly performance and boat length was almost zero ($r = -.019$). The present data for area 5 therefore did not show a relationship between the length, gross tonnage, and bhp of the trawlers and their absolute fishing power with respect to the tarakihi.

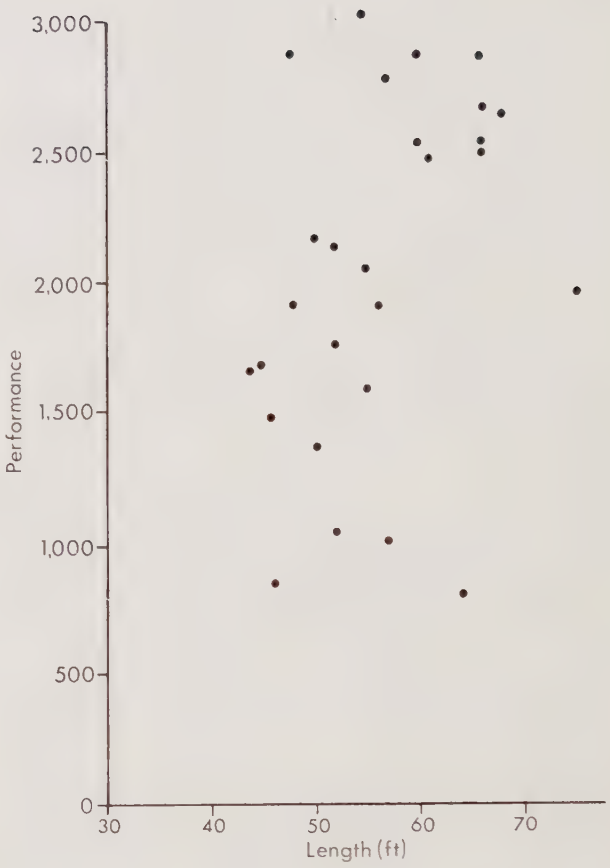

Fig. 18: The tarakihi performance (in pounds/day-at-sea) and overall length of all motor trawlers operating in area 5 in 1966 with annual landings consisting of 50 percent or more of tarakihi.

APPENDIX 3: LIST OF COMMON AND SCIENTIFIC NAMES

The scientific names given below are taken from Doogue and Moreland (1961) or, for species not listed there, from Waite (1911) and Chilton (1911).

Barracouta:	*Thyrsites atun*
Blue cod:	*Parapercis colias*
Elephant fish:	*Callorhynchus millii*
Flounder:	General name for the four *Rhombosolea* species occurring in New Zealand: dab or sand flounder, *R. plebeia;* yellowbelly flounder, *R. leporina*; black flounder, *R. retiaria*; greenback flounder, *R. tapirina*
Horse mackerel:	*Trachurus novaezelandiae*
Kahawai:	*Arripis trutta*
Red cod:	*Physiculus bacchus*
Red gurnard:	*Chelidonichthys kumu*
Rock lobster:	*Jasus edwardsii*
Snapper:	*Chrysophrys auratus*
Sole:	Includes lemon sole, *Pelotretis flavilatus*, and common sole, *Peltorhamphus novaezeelandiae*
Southern hake:	*Merluccius australis*
Southern kingfish:	*Jordanidia solandri*
Tarakihi:	*Cheilodactylus macropterus*
Trevally:	*Caranx lutescens*
Warehou:	*Seriolella brama*
Yellowtail:	*Seriola grandis*

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